

BIOLOGY FOR BEGINNERS

TRUMAN J. MOON

BIOLOGY *for* **BEGINNERS**

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by **TRUMAN J. MOON**

Reproduced in Facsimile

Foreword by Milton Hopkins

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BIOLOGY
FOR BEGINNERS
SECOND EDITION
BY
J. W. MOORE
AND
J. W. MOORE
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FOREWORD

One of my most interesting recent experiences has been the perusal of both the original edition of Truman J. Moon's **BIOLOGY FOR BEGINNERS** and the 1981 revision of Otto, Towle, and Bradley: **MODERN BIOLOGY**. It is hard to believe that the latter is a direct outgrowth of the former and that a period of sixty years separates them. My first impulse was to ask myself whether biological science had changed *that* much since my retirement some fifteen years ago. The answer is, of course: "It has." I think the publisher has kept up with the times and has made what was always a good book, even better.

The late Henry Holt, a distinguished publisher of trade and college textbooks, felt that the secondary market had been sorely neglected and subsequently endeavored to fill the void and meet the needs with outstanding texts in several fields. Although his books in all the areas of secondary school teaching were exceptionally fine, he was perhaps most successful in science with Moon's biology text and Dull's books in chemistry and physics. Moon was not only a splendid writer but also a gifted teacher and a great philosopher. These personal qualities found their way into his book with the result that it became an immediate success. From a broad and thorough study of basic biology, Moon believed that students should be prepared to do the more difficult work in college biology and could derive maximum learning experience if they had a knowledge of vocabulary and concepts. Independent work should also be provided for those who wished to undertake it. But the student was, to Moon, only a part of the picture. The teacher was equally important and hence any textbook should be teacher oriented. **BIOLOGY FOR BEGINNERS** was certainly all that.

As the years passed, Moon came to feel that having a collaborator, someone who felt the same as he did about the teaching of biology, was essential. Paul B. Mann of New York City became that collaborator, and their co-authorship lasted through several editions of the book. In the mid-1940's, however, both authors died; Paul Mann in 1943 and Truman Moon in 1946.

By that time the search for another, younger collaborator had already begun. Teachers from several areas were asked to give their

comments for a revision. They were personally interviewed and then recommendations were sent to the editorial office in New York. It became increasingly clear that James H. Otto of the George Washington High School in Indianapolis seemed to offer the most penetrating analysis of the Moon and Mann text, and he was invited to come to a sales meeting in New York to express further his views on biology teaching and writing. He won immediate acclaim from all present and was signed to a contract in 1942. Both Mrs. Moon and Mrs. Mann were happy that their husbands' book would be continued, and it was thought that Otto's work would give the text the new impetus that it required.

All was not, however, well with the new author. It was wartime and he was employed after school and in the evenings by a firm doing war research and thus had no time for writing. Fortunately, after a year or so he was able to devote most of his nonschool hours to writing, and since Holt had set 1947 as the publication date, it meant that manuscript had to be completed very early the year before. This revision was to be quite different in many ways from the old "blue Moon" (as previous editions were affectionately called by salesmen and teachers because of the blue cover). It would emphasize the newest discoveries in biological science but would still follow the basic philosophy of teaching that Moon had so successfully initiated. Otto believed that students should be led slowly into the subject matter and that this material should stimulate them to become interested in life around them and to cause them to think what it means to be alive. The arrangement of the units enabled teachers to go straight through the book with a class of gifted students or to omit those units which might hinder a group of slower students. Always, and throughout, the text was still teacher oriented, and the style of writing was still clear, understandable and meaningful, the same standards Moon had set earlier. It is interesting to note that the unit on genetics makes no mention of RNA, DNA, or the genetic code although the Rh factor in blood was given special prominence. In those post-war days molecular biology was still in its infancy. Rereading Otto's Preface to the 1947 revision, I realized again what a perfect gem of an essay it is.

While Otto was laboriously putting his idea on paper at home every evening and after school and on weekends, the Holt editorial office was in a quandary. Who on the very small staff was competent to deal with a biology textbook? The English editor felt that perhaps she was the logical person for the task and actually began editing a few

chapters. The social studies editor — the most senior member of the staff — decided that perhaps the responsibility should be his. The vice president settled the matter by inviting me to join the staff. I accepted with considerable trepidation because although I had an A.M. and a Ph.D. from Harvard “*In Rei Biologicae*” and had been Chairman of the Department of Biological and Earth Science at the University of Oklahoma for nine years, I was a complete novice in the secondary school classroom. With the sales staff, I set up a program that allowed me to travel with them, visiting classrooms and talking to science teachers and administrators everywhere, as well as observing how science was taught to young students. So we set out to cover the country visiting and visiting, and left the poor author writing, writing, and writing.

Eventually the day came, as I knew it should, when Otto requested a meeting with this editor from the ranks of academe whose initial ignorance of secondary school teaching was abysmal (word reached him quickly enough!). On my arrival in Indianapolis I phoned the author who told me to take a street car and get off at his school where he would await me. I shall never, ever, forget that first meeting. This tall, handsome and very distinguished man was standing on the steps of the school with his broad smile and his warm handshake of welcome. Within five minutes we were “Jim” and “Milton” and a deep, long friendship began.

Otto and I found mutual agreement in views on the teaching of biology. He was exceptionally persistent on what classroom teachers wanted in a textbook so that when I suggested something I had tried at the University, he reacted quickly with: “No, Milton, I’m sorry but that won’t work.” We wrote the first edition of BIOLOGICAL INVESTIGATIONS during a steaming Indiana summer, he working during the day at home and I in my scalding-hot hotel room and then comparing our work in the evenings after dinner. We had an ingenious manuscript to work from which had been sent in by another teacher and he became the co-author of that workbook.

When any of Otto’s manuscript arrived on my desk in New York I had comparatively little work to do on it because so much had already been done by correspondence and by telephone. His death in October 1972 was a great personal loss to me and I realized that my staunchest and warmest friend was gone. I was happy to represent the company at his funeral and pleased that his widow asked me to be one of his pall bearers.

As I peruse the 1981 edition of this famous book, I am delighted to find that the basic teaching philosophy of the three deceased authors has been retained, even to readability level. I like the many teaching aids (some of which I wish that Otto and I had thought of!), and I cannot conceive of any teacher failing to achieve success as he or she uses the book. Its content is completely up-to-date and well chosen. One can with complete candor say that this edition indeed represents the modern of its title. Other texts with other approaches have appeared and disappeared, but the publishers have "kept the faith" with the "old blue Moon" and the "old red Otto" and have listened to the advice and guidance of their peers.

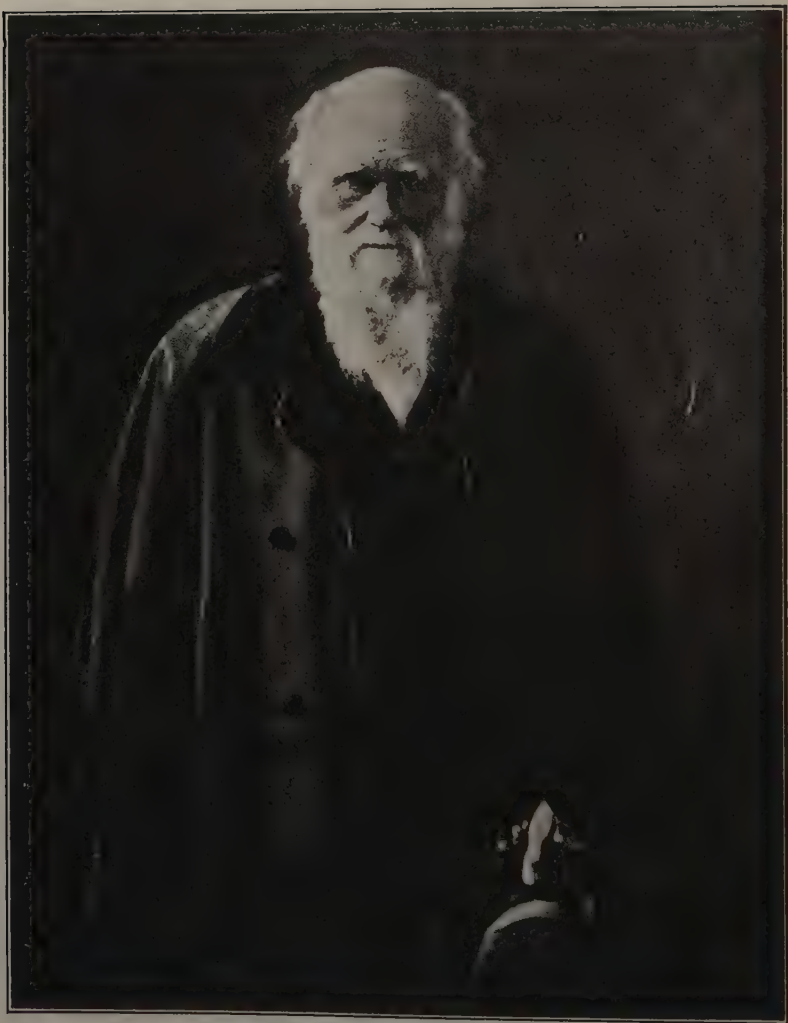
Yes, the content of biology has changed considerably since 1921. Today's advances with the benefit of modern technology, including the electron microscope, have changed our knowledge and our concepts. But what a joy teaching will be for instructors who are fortunate to have that magnificent book as the key to their success, a fitting descendant of this **BIOLOGY FOR BEGINNERS**.

Milton Hopkins
Former Editor-in-Chief, School Department
Holt, Rinehart and Winston, Publishers

PUBLISHER'S NOTE

With great pleasure and considerable pride we present this facsimile edition of a classic American textbook, BIOLOGY FOR BEGINNERS by Truman J. Moon. This book is a faithful reproduction of the first printing of the 1921 Edition. Circulating this facsimile is our way of commemorating what the 1921 Edition was to become, year after year, revision after revision, a veritable 60-year-old institution in itself. The publication of the 1981 Edition of MODERN BIOLOGY marks the start of the seventh decade of continuous publication of this title which began with the 1921 Edition. We salute the tradition that forges successful relationships among teachers, authors, and publishers to the benefit of American school children. We hope you share our pleasure and pride.

*January, 1981
New York, N.Y.*



CHARLES DARWIN 1809-1882

BIOLOGY FOR BEGINNERS

BY

TRUMAN J. MOON

MIDDLETOWN, N. Y. HIGH SCHOOL



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HENRY HOLT AND COMPANY

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PREFACE

THIS text is an attempt to present the fundamental facts of elementary biology as clearly and briefly as a reasonable scientific accuracy will allow. Three years' use in manuscript form has dictated the topics included and the arrangement followed in order that the book may be easily taught and readily understood.

The course emphasizes the fact that biology is a unit science, based on the fundamental idea of evolution rather than a forced combination of portions of botany, zoölogy and hygiene.

Emphasis has been placed upon a logical arrangement within the chapters, so that it is easy for the pupil to study, outline, and remember each lesson.

A larger proportion of pages is devoted to outlines, tabulations, and diagrams than in any other similar text. This means that the pupil has less text matter to cover, and more help to assist him in doing it.

No laboratory work is included. Any laboratory manual can be used with the text, however, as it covers much more than the required ground. It is thought that a separate manual will allow the teacher to emphasize in the laboratory, those subjects which he considers most important.

Experience has indicated that the "vocabularies" save the pupil much time and confusion. Particular care has been taken to keep the vocabulary of the text as simple as possible. Careful explanations are made where this seems advisable. The definitions in the text are not complete, but, for the sake of clearness, are purposely limited to those meanings which fit the use in the chapter concerned.

In any science subject collateral reading is highly important. To facilitate this, lists of references have been placed at the ends of the chapters, covering such books as should be available in a well-equipped school. This outside reading should be encouraged.

The large number of line drawings is intended to simplify matters of structure for the beginner who would have difficulty in selecting the essential points of a more detailed drawing or photograph. Since the object of illustrations in an elementary text is to call attention to essential facts, the simple diagrammatic outlines and complete labeling found in this book are worthy of notice. It is hoped also that a reasonable use of line drawings will help the pupil in his own work by affording models which he can easily approximate.

The economic applications of biology have been given very full treatment, especially as to their bearing on agriculture and civic problems.

The scope of the matter presented is broad enough so that the teacher can select what seems most important, and still be sure of covering any requirement in any elementary biology syllabus. On the other hand the attempt has been made not to burden the pupil with matter required for advanced biology only.

ACKNOWLEDGMENT

IN offering this text book to the public, recognition is due to many sources of aid and information.

The lists of references appended to the various chapters fulfill the double purpose of indicating some of the authorities which have been consulted and of telling the student where fuller information may be obtained.

The cuts, in so far as they are not original, are credited to the proper sources in each case. In many cases, these are changed in some degree, to conform to the uses of the text.

The author is especially indebted to the cheerful assistance of his wife in the laborious task of reading and correcting the manuscript and proof, and to his fellow teacher, Miss C. E. Reed, for many helpful suggestions as to content and arrangement.

If there be aught of use or value in this book let it be to the credit of the authorities consulted and the help received; for its many shortcomings the author alone is responsible.

T. J. MOON

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BIOLOGY FOR BEGINNERS

CHAPTER I

INTRODUCTION

The student should make sure that he understands every term used in his Biology lessons. This book will include vocabularies like the following, but in addition, a good dictionary should be consulted frequently and derivations studied. As is shown in the first paragraph on this page, a great deal can be learned about the meanings of scientific terms by looking up their derivations.

Vocabulary

Domestic, tamed, as applied to animals and plants used by man.

Biology, the science of living things.

Organic, pertaining to living things.

Inorganic, things which have never been alive.

Biology is a study of living things. The dictionary tells us that this term comes from two Greek words, "Bios" which means "life," or "living things," and "ology," a word-ending meaning "the science or study of." The two parts thus make a perfect definition of biology, which is, truly, "The science of living things."

Classes of Things. All things in the world can be divided into two classes; those which are, or have been alive, and those which have never lived. The former are called *organic* substances, and the latter *inorganic*.

Organic things include both plants and animals, together with all substances derived from them. Inorganic things include the members of the mineral kingdom such as stone, glass, or iron, as well as water, carbon dioxide, oxygen and similar substances. Biology is the science which deals with the study of organic things, as its derivation shows.

Words as Tools. Since three new words have been used already — biology, organic, and inorganic — it may appear that the subject

is to be made difficult because of many hard and strange terms. There need be no alarm at the prospect if we will consider each new word as a tool which will enable us to do our work better, more accurately, and more easily.

It is simpler to say "organic substances" than to say, "substances which are or have been alive." It is also more accurate, and furthermore we have increased our vocabulary by the addition of this new tool.

We should think a carpenter very foolish who cut all his lumber with a jack knife because he thought it too much trouble to learn to use a saw. Students in their school life are workmen, and their most important tools are *words*. Each subject taken up, like different kinds of carpenter work, requires the use of a certain number of new tools (words). These must be learned before the student can do his work efficiently.

On the other hand a carpenter would be foolish to load up his chest with a lot of tools which he rarely used, and so, in our study, we have included only those new names and terms without which we could not possibly get along. If we learn to use them, we will not have to "cut off our board with a jack knife."

Sciences Included in Biology. Although biology is a single and closely united science based on the study of all things that are or have been alive, it is so broad in scope that it includes many special branches.

Some of these are already familiar, such as botany, which deals with plants; zoölogy, which deals with animals; hygiene, which concerns the care of the human body; physiology, which is the science of the use or function of living organs; and many others.

Familiar Biology. To begin with, each one of us has studied biology already by observing the things of nature about us. Is this not true? We know some plants and trees by name. We know how to cultivate gardens, what will help plants grow, the names of many flowers. All of us buy and use fruits, grain, and vegetables. We also know something about the care of animals, and, most important of all, are anxious to learn all that we can about the care and use of our own bodies.

Reasons for the Study of Biology. Biology is a required study in many schools, and we have a right to ask why it is considered so important that we are obliged to study it.

In the first place there are few subjects that add so much to

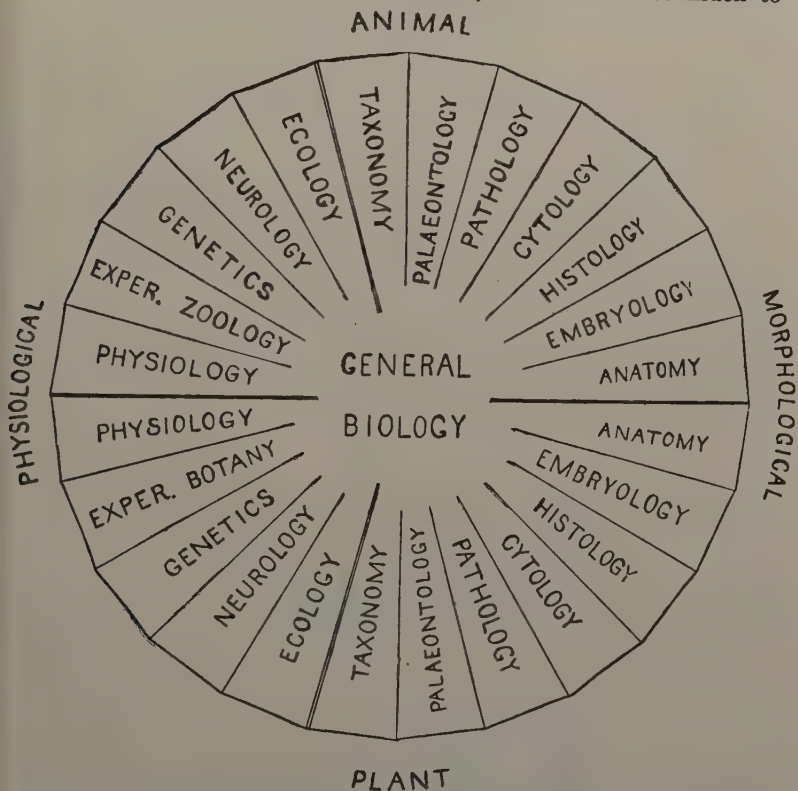


FIG. 1. Diagram to show the relation of General Biology to the biological sciences. From Calkins.

general culture by increasing the number of things in which we are interested and about which we should have information.

Few people really *see* very much of the things about them — accurate observation is a very rare but valuable trait, and biology will greatly increase the powers of observation.

Mere observation of facts is not enough, however, for one should be able to draw correct conclusions from what he sees. This ability to think and reason is one of the chief aims of the laboratory work in biology or any other science.

Although these reasons for the study of biology are by far the most important, others can be mentioned which may seem more practical. It is the foundation of farming, gardening, and forestry and upon its laws are based the care and breeding of all domestic animals and plants.

In even a more personal way, biology deals with the health and care of our own bodies — *hygiene*. It also includes the study of the cause and prevention of disease, the work of bacteria, and means of maintaining healthful surroundings — *sanitation*.

One-half of all human deaths are caused by germ diseases and at least half of these could be prevented by proper knowledge and practice of *hygiene* and *sanitation*. This in itself is sufficient reason for interest in the study of biology.

SUMMARY

Biology, a study of living things.

1. Derivation: *Bios*, *Logos*.

2. Definition.

3. Classes of things.

Inorganic (meaning and examples).

Organic (meaning and examples).

Plants.

Animals.

4. Words as tools.

5. Sciences included.

6. Familiar biology.

7. Reasons for study.

Adds to culture.

Cultivates power of observation.

Teaches to think and reason.

Importance in many industries.

Relation to health.

Hygiene.

Sanitation.

CHAPTER II

THE LIKENESS OF ALL LIVING THINGS

Vocabulary

Similarity, likeness.

Assimilation, "to be made the same," that is, the process by which food stuff is made into tissue.

Nutrition, all the processes by which food is prepared and assimilated in the body.

Excretion, the passing off of waste matter from plant or animal.

Biology, then, is the study of organic, or living things, and living things include both plants and animals. At first one would say that plants and animals have very little similarity and that it would be difficult to study them together, but let us see if this is true.

Nutrition. First, both plants and animals are alive and grow in size and that means that they *both need food*. A cat, for instance, has to eat, and a geranium has to have earth, in order to live. The cat uses organic food and the plant inorganic. The cat obtains its food by means of its claws and teeth, while the food-getting of the plant is done largely by the roots. They are both dependent on food.

After they get their food, both plants and animals have to put it into liquid form in their bodies. We call that process *digestion*. Then the digested food undergoes a change by which the milk or meat actually becomes part of the cat, while the plant foods become part of the geranium. This is a very wonderful process and is called *assimilation*. (Look up this word in the dictionary and see if you can tell why it is used in this way.)

Food-getting, digestion, and assimilation together make up the process of *nutrition* (getting nourishment). The animal and the plant have this process in common.

Respiration. Another point in which our two examples are alike is that they both breathe. If we keep either one in an air-tight box it will die. The cat breathes by means of its lungs and it is easy to see the muscular movements involved. The leaves of the plant breathe too, although our eyes cannot detect the way in which this is done. The process of breathing is called *respiration* in both cases.

Excretion. Both cat and geranium use the food that they assimilate to build up their bodies or to give them energy, and both throw off from their bodies unused and changed food materials by a process called *excretion*. The animal does this by means of the lungs, skin, intestines and kidneys; the plant by means of the leaves.

Motion. Another way in which all living things are alike is in the power of *motion*. It is easy to see the cat move, but few observe how the geranium turns its leaves to the light and its roots to the water. Though animals usually have greater freedom of motion, plants do not lack it altogether.

Sensation. In a general way, all plants and animals have the power of responding to touch, heat, light, and other forces outside of themselves. This is *sensation*, and may vary in its expression, from the mere turning of leaves toward light to the delicate operation of a wonderful sense organ like the human eye.

Reproduction. Both plants and animals *reproduce* others like themselves. Kittens are born and grow to be cats, and the plant bears seeds which will produce other plants like itself. By this wonderful provision of nature, although all organic things die, others like them are left to take their places. The processes of reproduction and nutrition are the two most important characteristics of all living things.

Likeness of all Living (Organic) Things. The cat before the fire and the geranium on the window sill, though apparently different, are really alike in all of the necessary processes of life. It is, therefore, possible and easy to study plants and animals together. Biology is not merely botany plus zoölogy, but a study of the life processes of all living things.

Difference from Inorganic Things. The points, in which all living or organic things are alike, are also the points in which they differ from inorganic things. A stone and a piece of iron are familiar examples of inorganic matter. We cannot imagine a stone taking food or growing, or a piece of iron moving or reproducing its kind. Our study of biology is thus sharply separated from inorganic things.

To be sure, plants can take inorganic matter and by certain wonderful processes make it into the living plant as we have mentioned. But it then ceases to be inorganic and becomes a part of the plant. Plant and animal are alike in all essential ways and they also differ in these ways from all inorganic substances.

SUMMARY

Organic things (Plant and Animal).

1. Live, grow, and move.
2. Obtain food.
3. Digest and absorb food.
4. Assimilate food as part of themselves.
5. Excrete waste.
6. Reproduce.

Inorganic things can perform none of the above processes.

Organic and Inorganic things resemble each other in the following points:

1. They are composed of similar elements.
2. They contain, use and produce similar compounds, such as carbon dioxide, water, etc.
3. They have characteristic shapes and weights.
4. They undergo chemical changes.
5. They liberate energy.

Organic things differ from **Inorganic**, in the following points:

1. They have organs for various functions.
2. They are composed of cells.
3. They always contain protoplasm.
4. Their growth is from within.
5. They respond to their surroundings (irritability).
6. They follow a "life cycle."
7. They depend upon oxidation for life.

PROCESSES IN WHICH ORGANIC THINGS ARE ALIKE

Process	In plants is performed by	In animals is performed by
Food-getting	Roots, leaves	Teeth, claws, etc.
Digestion	Ferments in the tissues	Stomach, intestines, glands, etc.
Absorption	All live tissues	Intestine, stomach, etc.
Assimilation	" " "	All live tissues
Respiration (oxidation)	Air spaces and tissues	Lungs, gills, etc., all tissues
Excretion	Leaves	Kidneys, skin, etc.
Motion	Flowers, leaves, tendrils, etc.	Legs, wings, fins, etc.
Sensation	Leaves, tendrils	Nerves, sense organs
Reproduction	Seeds, slips, etc.	Eggs, live young

What evidences can you give of any of these processes, in either plants or animals?

Since both plants and animals perform similar processes, what might you expect about the stuff they are made of?

COLLATERAL READING

General Biology, Sedgwick and Wilson, pp. 1-19; *Applied Biology*, Bigelow, pp. 10-22, 122-132; *Practical Biology*, Smallwood, pp. 1-10; *Essentials of Biology*, Hunter, pp. 26-30; *Elementary Zoölogy*, Galloway, pp. 36-54, 72-97; *Biology*, Calkins, pp. 6-15; *General Zoölogy*, Pearse, pp. 25-36.

CHAPTER III

ELEMENTS, THE ALPHABET OF ALL LIVING THINGS

Vocabulary

Individual, separate.

Innumerable, very many.

Oxidation, the union of any thing with oxygen.

Combustion, rapid oxidation, producing light and heat.

Restrain, to hold back.

All the words of our language are made from less than thirty letters. If we think of our big dictionaries we realize what an enormous number of different combinations can be formed from a few letters.

Elements and Compounds. In something the same way, all the matter in the world is composed of about eighty individual substances called *elements*. These we might think of as the letters in a chemical alphabet which spell all the substances — both organic and inorganic — that are in existence. When elements unite, they form all the innumerable things that compose the world around us. These substances, formed by the union of two or more elements, are called *compounds*. For example, iron is an element. Oxygen in the air is also an element. When these two unite, they form a compound which we call iron rust.

Organic substances utilize only about ten elements, but when we stop to think of the thousands of kinds of plants and of animals, and of all the different substances of which they are made, we see that ten elements are enough to make a wide variety of compounds.

What to Learn about Them. The complete study of these elements and their compounds is called chemistry, but for the present we need to learn only four things about the elements which compose organic substances: (1) their names, (2) where

they are found, (3) enough of their characteristics or properties so that we can recognize them, and (4) their use to living things.

OXYGEN

Where it is Found. We already know that oxygen (O) is part of the air, but it is also a part of water, sand, soil, rock, and many other things. It may be hard to understand how a gas, like oxygen, can be a part of a liquid, like water, or of a solid like wood, but this is true. Oxygen is found in all plant and animal substance. In fact it is the most abundant element in the world, and is itself one-half of the solid material of the earth.

Properties. We shall see oxygen prepared in the laboratory, and shall discover that it is a colorless, odorless, and tasteless gas. It is heavier than air, will dissolve slightly in water, and most curious of all, though it will not burn, it nevertheless makes other things burn very rapidly. Iron, copper, and many other substances which do not seem to burn at all in the air will do so in oxygen, while sulphur and wood, which do burn in air, burn very fast in oxygen.

Test. It is the only substance which will cause a glowing splinter to burst into flame. This fact is utilized in testing whether a gas is oxygen or not, and is therefore called a *test* for oxygen.

Oxidation. When anything unites with oxygen, the process is called *oxidation*, and the compound formed by the substance and the oxygen is called an *oxide*.

Oxygen may unite with substances rapidly, as when a stick burns, or slowly, as when iron rusts. An oxide is always the product, and there is always a more important product, namely, *heat energy*.

Both plants and animals use oxygen. Heat energy is necessary for all life. All plants and animals therefore depend on oxygen which they take into their bodies by breathing, as we have seen in Chapter II. As the living tissues become oxidized they produce heat and energy, leaving a residue of oxides and other material to be thrown off as waste. The food assimilated as tissue contains the vital energy which oxidation releases.

Live and Dead Engines. A living organism is often compared to a steam engine. Both need a supply of food (fuel), and both must have oxygen to unite with (oxidize) the food and set free its energy. In both, heat is produced by this oxidation and then changed into motion, and in both there are waste products which have to be removed.

But an engine is only an inorganic thing. It cannot get its own food, it does not assimilate or grow, it does not excrete its waste products, or reproduce. Really the only way in which it resembles a living thing is that it depends on energy which is released from substances by uniting with oxygen, and turns this energy into motion.

RESEMBLANCES

	A living organism	A steam engine
Requires	Food	Fuel
To unite with	Oxygen	Oxygen
By means of	Respiration	Draft
To produce	Heat and energy	Heat and energy
Leaving waste	Unused food	Ashes
	Carbon dioxide (in breath)	Carbon dioxide (in chimney gas)

DIFFERENCES

	A living organism	A steam engine
	Is alive	Is not alive
	Grows in size	Does not grow
	Repairs wear	Wears out
	Reproduces	Cannot reproduce

Similarities based on oxidation, differences based on functions of the protoplasm.

Other Uses of Oxygen. Oxygen has many other uses in nature. It causes combustion from which we get heat and power. It also causes rusting, oxidation, and decay. Its myriad compounds are

absolutely necessary as food and drink. But its chief importance in biology is that, by uniting with the substance of both plant and animal, it sets free the energy which keeps them alive. Without oxygen, no life can exist.

NITROGEN

Where it is Found. Nitrogen (N) is another important element. It makes up four-fifths of the air. It is found combined with several minerals in the soil and exists in the living tissue of all organic things.

Properties. Nitrogen resembles oxygen in being colorless, odorless, and tasteless, and in that it will not burn. It is less soluble in water and lighter in weight. It is the exact opposite of oxygen in its behavior, for it will not cause combustion, nor will it combine readily with other elements. Its compounds decompose easily.

Uses. It is found in the active living substance of all plants and animals and is essential to their life. Its various compounds are our most necessary foods.

All fertilizers which we use for plants, as well as meat, milk, eggs, and many other animal foods contain very important compounds of nitrogen.

If the air were pure oxygen, fires could not be controlled and things would oxidize too rapidly. Thus, another important use of nitrogen is to restrain the activity of oxygen and make the atmosphere suitable for life.

HYDROGEN

Where it is Found. Hydrogen (H) occurs combined in water, plant and animal tissue, wood, coal, gas, and all acids.

Properties. It resembles both nitrogen and oxygen in being colorless, odorless, and tasteless. It does not dissolve much in water and it will not cause things to burn, but unlike either nitrogen or oxygen it burns readily and even explodes when mixed with air and brought into contact with fire. It is the lightest substance known and, because of this fact, is used to fill balloons.

Uses. Hydrogen is important to the biologist because it unites readily with oxygen and forms water. It also combines with both oxygen and carbon (another element) and forms a whole series of compounds called fats, sugars, and starches. It is an essential ingredient in all organic tissue.

CARBON

Carbon (C) is an element with which we are more familiar; coal, charcoal, and wood are common forms. Lead-pencils do not really contain lead at all but another form of carbon called graphite. Strangest of all, the diamond is carbon, too, though not a common form.

Properties. Carbon is (except in the diamond) a black solid, not soluble in any thing. At ordinary temperature it is very inactive. When heated, however, it unites readily with oxygen, (that is, it burns) and forms an oxide which is called *carbon dioxide* — a compound very necessary to plants, as we shall see later.

Uses. Carbon's importance to biology is due to the fact that it is a part of all organic substances, combining with hydrogen, nitrogen, and oxygen and other elements to form all plant and animal tissues and many of their foods.

We know that if any plant or animal substance is partly burned a black solid is produced. This, in every case, is carbon. We also know that if the burning is continued the carbon will disappear. This means that it becomes oxidized into carbon dioxide, which is an invisible gas.

Plants *alone* have the power to obtain their carbon from the carbon dioxide of the air. Animals depend entirely on plant foods for the carbon compounds which are necessary for their life.

SULPHUR

Sulphur (S) is a yellow solid element, which (like carbon) will not dissolve in water, but can be dissolved in other chemicals.

Sulphur itself has no odor, but it readily unites with oxygen, even at low temperatures. It also burns readily, producing in

both cases an oxide of sulphur (SO_2) with the familiar, suffocating odor which we wrongly associate with sulphur itself.

Its importance in biology is due to the fact that it is a part of the living substance of all organic things though in smaller amounts than any of the preceding elements.

Mustard, onions, and eggs will blacken silver dishes. This is due to the sulphur compounds which they contain; but sulphur, in smaller quantities, is found in all plants and animals.

PHOSPHORUS

Phosphorus (P) is a light yellow, waxy, solid element. Like sulphur, it dissolves in several other liquids, but not in water.

It also resembles sulphur in that it unites readily with oxygen. In fact it unites with oxygen more readily than does sulphur, for, if exposed to air, it will take fire and burn fiercely, forming an oxide of phosphorus. It has to be kept covered with water to prevent it from burning and is a dangerous and poisonous element.

It seems strange that such a substance should be a necessary ingredient of our bodies and, in fact, of all living things. To be sure it is present in small amount but is absolutely essential, being especially abundant in bone and nerve tissue.

You have probably heard plant fertilizers called "phosphates." This is because they contain phosphorus compounds.

IRON

Iron is another element. We are familiar with it as a heavy, solid metal; and we know it unites slowly with oxygen forming iron oxide (rust). This is about the last thing we would think to be of use in the bodies of plants or animals. However, iron is absolutely necessary in the green coloring matter of plants and in the red blood of animals. Later we will learn the remarkable services which its compounds perform in these substances.

SODIUM, POTASSIUM, AND CALCIUM

Our list of elements important to organic life will end with three similar ones — sodium, potassium, and calcium. These are light, metallic substances which burn when put in water and are therefore very dangerous to handle. Potassium compounds must be in the soil if plants are to thrive, while sodium and calcium compounds are necessary for the blood and skeleton of animals.

Nitrogen, sulphur, phosphorus, iron, sodium, potassium, and calcium are all obtained from their mineral compounds in the soil; animals use salt (a sodium compound) directly, while they get the other elements from plant foods. Plants in turn obtain them from the soil.

By themselves, all these elements are inorganic substances, but in the wonderful process of assimilation, plants and animals can combine them to form the living stuff of which their tissues are made. On the other hand, by the processes of oxidation, death, and decay, the complex organic compounds are broken up into simpler forms, and return to the soil or air as inorganic compounds or elements, to be used over again by organic things.

Here is an estimate of the composition of the human body, which may give an idea of the comparative amounts of the different elements in animal tissue.

A person weighing 154 pounds would be composed of:

Oxygen	97.2	pounds
Carbon	31.1	"
Hydrogen	15.2	"
Nitrogen	3.8	"
Calcium	3.8	"
Phosphorus	1.75	"
Sulphur	.27	"
Chlorine	.25	"
Fluorine	.22	"
Potassium	.18	"
Sodium	.16	"
Magnesium	.11	"
Iron	.01	"

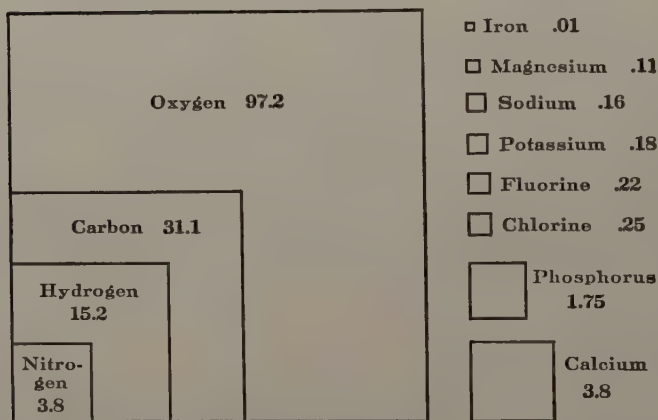


FIG. 2. Elements composing a human body weighing 154 pounds. (Figures express pounds.)

COLLATERAL READING

See index of any text book in Elementary Chemistry. *Applied Biology*, Bigelow, pp. 5-9; *Elementary Biology*, Peabody and Hunt, pp. 5-13; *Essentials of Biology*, Hunter, pp. 17-25.

SOME ELEMENTS

Element	Where found	Properties	Uses	Test
Oxygen	Air, water, soil ($\frac{1}{5}$ of air)	Gas, colorless, odorless, tasteless, soluble, very active, causes things to burn, oxidizes	Respiration, combustion, decay, releases energy	Causes glowing splint to burst into flame
Hydrogen	Water, organic tissue	Gas, colorless, odorless, tasteless, very light, burns, explodes, extinguishes flame;	Component of all nutrients and organic tissues, part of water	Explosion when mixed with air and lighted
Nitrogen	Air, soil, nitrates, proteids ($\frac{1}{4}$ of air)	Gas, colorless, odorless, tasteless, neither will burn nor cause things to burn, inactive	Supply nitrogen compounds for soil and all active tissues	Extinguishes flame and does not turn lime-water milky
Carbon	Organic tissue, coal, graphite, wood, etc.	Solid, black, insoluble, burns, forming CO ₂	Component of all nutrients and organic tissues	Production of CO ₂ when burned
Sulphur	Mineral compounds, proteids, eggs, mustard, etc.	Solid, yellow, insoluble in water, tasteless, burns forming SO ₂	Essential in protoplasm and bone tissue	Odor of SO ₂ when burned
Phosphorus	Mineral compounds, phosphates, bone	Solid, waxy, yellow, burns readily, poison	In protoplasm, seed, nerve, and bone	Ease of burning
Iron	Soils, ores	Solid, heavy, white, oxidizes or "rusts"	In chlorophyll and red part of blood	Its properties Unburned ash
Calcium	Rock, soils, salt, limestone, etc.	Solids, soft light metals, react with air and water	Compounds essential in blood, bone, and plant tissues	Flame colors: Sodium, yellow Potassium, violet Calcium, orange
Sodium				
Potassium				

CHAPTER IV

COMPOUNDS, BIOLOGY'S BUILDING MATERIALS

Vocabulary

Extinguish, to "put out" a flame.

Constitutes, composes.

Converted, changed.

Emergencies, sudden needs.

Distinguish, to show differences between.

Characteristics, properties by which a substance may be known.

We have learned the names and something about the characteristics of a few of the elements. In dealing with these elements and their compounds it is necessary to find some way to distinguish one from another, in order that they may be properly studied.

Method of "Testing" Substances. Such means of distinguishing are called "tests" and we have already referred to one in the case of oxygen. The test consisted in the fact that oxygen, and *no other substance*, would cause a glowing spark to burst into flame.

Before taking up any test three things must be considered.

1. A substance known to be the one we are studying must be tested, so that we may know the correct result, and be able to recognize it in an unknown case.

2. The test must be true of the substance sought, and of *no other*. You can readily see, that if even one other gas would kindle the glowing splinter, then that could not be used as a test for oxygen.

3. The test must be made in the same way, every time, or else one might suppose that the result was affected by the difference in treatment.

INORGANIC COMPOUNDS

Carbon Dioxide. When carbon unites with oxygen, it forms a colorless, odorless, and tasteless gas called carbon dioxide (CO_2), which is heavier than air and will extinguish a flame.

Carbon dioxide is like nitrogen in many ways (mention them), but if it be mixed with *lime water*, it causes the clear liquid to become *milky*, while nitrogen does not. This is the test for carbon dioxide.

Carbon dioxide is a plant food; plants having the power to take this gas from the air, combine it with water, and make it into their tissues — in fact it is from this source that all organic carbon comes.

Water. When hydrogen combines with oxygen, water (H_2O) is formed as we found when studying hydrogen. This compound is so familiar that we do not need to learn any test for its presence. It may be well to realize, however, that water constitutes much over half the weight of all organic matter; that it is absolutely essential to all life; and that it is not only a food, but a means of carrying food to the tissues of all plants and animals.

Mineral Compounds. The next compounds we shall take up are made of the elements mentioned last in our list: sulphur, phosphorus, iron, potassium, sodium, and calcium.

Calcium unites with sulphur and oxygen to form calcium sulphate, and with phosphorus and oxygen to form calcium phosphate. Sodium and potassium unite with oxygen and nitrogen to form sodium or potassium nitrates and so on with many other compounds.

Fortunately we do not have to learn to test for these separately. When found in organic tissue, they are usually grouped together and called "mineral matter" or "mineral salts," and the fact that they remain as ash, when organic matter is completely burned, is a sufficient test for these compounds at present.

Notice that all the elements except carbon and hydrogen may exist, combined as mineral compounds, in the soil where the plants can get them. Hydrogen is obtained from *soil water* and carbon from the carbon dioxide of the air.

All the compounds mentioned so far, water, carbon dioxide, and numerous mineral salts, are inorganic substances.

One of the most important ways in which plants differ from animals is that they can use inorganic substances solely for food

and recombine them into organic compounds, a thing which no animal can do. Nor can we imitate it in any laboratory experiment.

Though animals use water and some mineral salts, they depend for their life on the organic compounds made by the plants. Flesh-eating animals live on other animals, which in turn use plant food. The fact that plants can use inorganic food, while animals depend on plants for their inorganic nourishment, is one of the most important facts for us to remember.

Of course the plant forms these organic compounds for its own growth and food, to be stored away by the plant and used when necessary. Whenever we eat a loaf of bread or a piece of candy we are using material the wheat plant or sugar cane had assimilated and would have used as food for itself.

ORGANIC COMPOUNDS. NUTRIENTS

Fortunately, the very complicated compounds which the plants provide and which both plants and animals use for food and growth, can be grouped into three great classes called: (1) Proteids, (2) Carbohydrates, (3) Fats. These are sometimes taken all together and called *organic nutrients*.

Proteids. These are very numerous and are found in all living substances; the following are some that are common and found in large amounts.

<i>Proteid</i>	<i>Where found</i>
Gluten	in grains
Legumin	in peas and beans
Myosin	in lean meat
Albumen	in the white of egg
Casein	in milk and cheese

It is not necessary to learn these names but the list is put in to show that proteids are of many kinds and, though first provided by plants, are needed in animal tissue as well.

Test for Proteids. Proteids differ in many ways but there is one point in which they all behave alike and which is different,

from any other substance — hence we can use it as a test. If a substance supposed to contain any proteid is put into *nitric acid* and *heated* gently, it will turn bright yellow. Then if the acid be washed off and *ammonia* added the proteid, if present, will become *orange* color. This is the test for any proteid for no other substance will act in the same way.

The proteids are the most useful of the nutrients for they make up most of the active living substance of plant and animal; they are called tissue builders on this account. Proteids are composed of the elements carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, with sometimes mineral salts as well, so we see they are very complex organic compounds.

Carbohydrates. Next to proteids in importance to all living things come the carbohydrates. They are composed of carbon, hydrogen, and oxygen, with always twice as much hydrogen as oxygen, and varying amounts of carbon.

Carbohydrates are found almost entirely in plants, whose tissues they largely compose. When animals eat them, they either make them over into proteid tissue or else oxidize them as fuel to produce heat and energy. Some are converted into fats and stored as such.

Some common carbohydrates are:

The starches.

Corn starch	from corn
Potato starch	" potato
Flour starch	" wheat
Tapioca starch	" cassava root

The sugars.

Cane sugar	" sugar cane	} (saccharose)
Beet sugar	" sugar beet	
Grape sugar	" fruits	(Glucose)
Milk sugar	" milk	(Lactose)

Cellulose.

Complicated forms found in wood, paper, cotton, linen.

(Glycogen is an animal carbohydrate found in the liver of some animals and called "liver starch." It seems to be stored there for later use.)

It is a little strange to think of cotton and starch, or wood and sugar as being so nearly related, but they consist of the same three elements, and are produced by the plants from water and carbon dioxide. It would be a cheap diet, if we could take water from a reservoir and carbon dioxide from the air and make them into flour. Man has to depend on plants for this wonderful process, and can only begin where the plants leave off, using the plant-made carbohydrates for his food.

The Test for Starches. No one test can be used for all the carbohydrates, but we can test for any starch by dissolving the substance supposed to contain it in hot water and then adding a drop of *iodine*. The solution will turn blue if starch be present. No substance other than starch will act this way under these conditions.

The Test for Grape Sugar. There is no one test for all sugars, but grape sugar (glucose) is very common and can be easily distinguished from our household (beet or cane) sugar by what is known as the *Fehling Test* — so named from the man who devised it.

Two solutions are used in the Fehling test, one *colorless*, and one *blue*. When these are added in equal amounts to a similar amount of the substance to be tested, and the mixture *heated*, a *yellow-brown solid* will form if grape sugar be present. Cane or beet sugar will not act this way.

Fats. The last class of nutrients is the fats and oils, which are also composed of carbon, hydrogen, and oxygen. They differ from carbohydrates in having less oxygen. Hence they oxidize more readily and as a result their chief use is to produce energy.

Plants store fats in their seeds to supply energy for growth; animals store fats in various places and use them for the same purpose.

Kinds. Cotton-seed oil, olive oil, and the oils from various nuts are examples of vegetable fats; while lard, butter, and fat meats are familiar examples of fat from animals.

COMPOUNDS

Compound	Composition	Kinds	Where found	Use	Test
<i>Inorganic</i> Mineral salts	Potassium, sodium, calcium, N, S, P, iron	Phosphates, sulphates, nitrates, etc.	Soil, bone, seeds	Furnish N, S, P, etc., for protoplasm, supporting tissue	Remains as ash when compound is burned
Water	H ₂ O		Soil, air, organic tissue	Solvent, carrier, plant and animal food stuff	
Carbon-dioxide	CO ₂		Air	Plants make food of it (starch)	Turns lime water milky
<i>Organic</i> Proteids	C, H, O, N, S, P	Gluten Myosin Albumen Casein Legumin Starch	Grains Lean meats Eggs Milk, cheese Peas, beans Corn, wheat, potato	Tissue building Making protoplasm	Add nitric acid, heat causes yellow color. Wash and add ammonia. color deepens to orange
Carbohydrates	C, H ₂ , O	Sugars: sucrose glucose lactose Cellulose	Cane, beet Grapes, honey Milk Wood, paper, linen	Plant tissue, animal food for energy Energy-making food	Turns blue with iodine
Fats	C, H, O	Plant: olive oil cotton-seed oil nuts Animal: butter lard meats	Olives Cotton-seed Peanuts Milk Pork Beef	Plant tissue Energy-making foods	For glucose: brown color with Fehling test Crush, dissolve in ether and let ether evaporate, fat remains

Test for Fats. To test for fats the substance should be crushed as finely as possible and treated with ether. This will dissolve out any fat that may be present and can then be poured off. When the ether evaporates the fat will remain in the dish.

COLLATERAL READING

See index of any Chemistry Text for the Compounds mentioned. *General Biology*, Sedgwick and Wilson, pp. 33-40; *Biology*, Bailey and Coleman, Introduction; *Elementary Biology*, Peabody and Hunt, pp. 13-25; *Chemistry of Plant and Animal Life*, Snyder, see index; *Source, Chemistry and Use of Food Products*, Bailey, pp. 1-24; *Food Products*, Sherman, pp. 1-23; *Botany for Schools*, Atkinson, pp. 13-19.

CHAPTER V

PROTOPLASM, THE "BIOS" OF BIOLOGY

Vocabulary

Protoplasm, see text.

Fundamental, that upon which all else is built.

Essential, necessary.

Nucleus, most active part of cell protoplasm, controls growth and reproduction — usually visible as a denser spot.

Minute, very small.

Function, use or work of a special part.

Adaptation, fitness for use.

Environment, all that makes up the surroundings of any living thing.

Primary, first in origin and importance.

Since it appears that plants and animals are composed of the same elements and use similar compounds for food it would be only natural that their foundation material should be the same. This is, in fact, the case. The foundation substance is called *protoplasm*, a name derived from two Greek words, *protos* (first) and *plasma* (form or substance). It is well named, for it is the first and most necessary substance of all organic things.

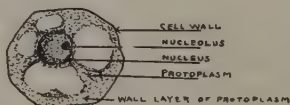
Protoplasm is *alive* and, in truth, the *only* living substance. We do not know what life is but we do know that as long as life exists in plants or animals, their protoplasm is active. When it ceases to act, death is the result.

Protoplasm may be defined as the fundamental, essential, living substance of all plants and animals. It is a jelly-like substance composed of carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus; but while we can analyze it and state its composition, we cannot combine the elements to make it. There is only one Power that can create life.

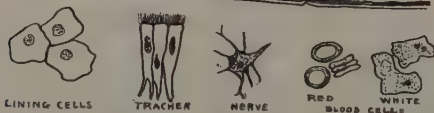
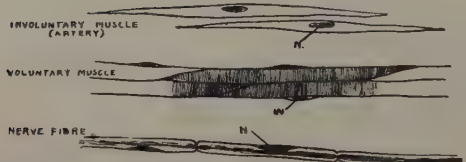
Because it is alive, protoplasm has certain remarkable properties:

1. It takes in, digests, and assimilates food.
2. It oxidizes food and excretes waste.
3. It grows in size and form.
4. It has power of motion.
5. It responds to light, heat, moisture, etc.
6. It reproduces.

DIAGRAM OF A TYPICAL CELL



ANIMAL CELLS



SOME PLANT CELLS

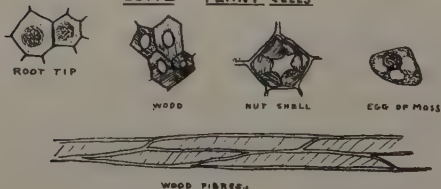


FIG. 3. Animal and plant cells similar in structure but varying in form.

We observe that this list is much like the one which gave the points in which the cat resembled the geranium. Now we can see the reason: both depend on protoplasm for life, so, of course, their life processes would be similar.

The Cell. In most plants and animals the protoplasm is divided into very small parts called *cells*. These are merely the simplest units of protoplasm of which the plant or animal is composed. A living cell usually consists of a tiny mass of protoplasm surrounded by a membrane called the cell wall. The central portion of the protoplasm, more active than the rest, is called the nucleus. The cell wall gives definite shape to the cell and the nucleus seems to regulate growth and reproduction. Cells are usually very minute, but are of innumerable shapes, varying with the special work they may have to perform.

Some plants and animals consist of only one cell. In more complicated animals, there are a great many different groups of cells, each fitted for some one purpose, as, for example, the vast number of cells that together make up a muscle and have developed especially the power of motion.

Tissues. A group of similar cells, devoted to a single use, is called a *tissue*. There are many kinds of tissues, as wood, bark, and leaf, in plants, and bone, muscle, nerve, etc., in animals.

Organs. In all the more familiar plants and animals, various tissues are grouped together to form a more complex part, which has some important general use. The stem of a tree, for instance, whose use is to support the leaves, flowers, and fruit, consists of wood, pith, bark, and other tissues, all working together for one purpose. The leg of a cat is made up of bone, muscle, nerve, and other tissues, working together to make locomotion possible. Such groups of tissues are called *organs* and the purpose or use of any part is called its *function*.

So we can say that all living things are composed of protoplasm; the protoplasm is usually divided into cells; the cells are grouped into tissues, and these, in turn, into organs fitted for some particular function or functions.

Systems. Often in the higher forms, especially among animals, several organs are grouped together to perform related functions. Such groups are referred to as *systems*, as, for example, the circulatory system, which includes the heart, arteries, veins, and capillaries. These are organs, all united in the work of circulation.

The comparison is sometimes made between a plant or animal and a book, as follows:

The elements	correspond to	the letters.
Compounds	correspond to	words.
Cells	correspond to	sentences.
Tissues	correspond to	paragraphs.
Organs	correspond to	chapters.
The plant or animal	corresponds to	the whole book.

To illustrate this method of structure we may look at the hand. It is made of millions of *cells*, as shown by the microscope, each having its characteristic shape and the usual cell parts: protoplasm, nucleus, and wall.

Numerous as these cells are, they can be classified into a comparatively few kinds. Groups of similar cells are called *tissues*, and we find in the hand, muscle tissue, bone tissue, nerve tissue, skin tissue, and some others. Each of these tissues has its special use. The muscle is used for motion; the bone, for support; and so on. All together they are combined into one *organ*, whose general function is prehension (grasping things).

In a similar way with plants, the *cell* is the unit of structure, and in a stem, for instance, there are several kinds of cells. These are grouped into wood *tissue*, bark tissue, tubular tissue, and pith tissue, each made of similar cells and each with different functions. However, they are all grouped together to form the plant *organ*, called the stem, with its general functions of support and circulation of sap.

Relation of Structure to Use. Organic things are composed of the same elements, combined in similar compounds, which appear as living protoplasm, whether of animals or plants. This protoplasm performs very similar functions in either case, but by very different organs. The plant gets its food by way of leaves and roots, while an animal like the cat uses its claws, teeth, and swiftness. Our whole course in biology deals with the essential life functions of plants and animals, but, in order to study these func-

tions intelligently, we must first know something of the structure of the organs concerned in their performance.

As soon as one understands structure in its relation to function it becomes apparent that each organ is wonderfully fitted for its particular work. This fitness of structure to function is called *adaptation*, and is a very important topic in all biologic study. Structure, function, and adaptation are the foundation stones of our subject and will always be presented in the order here named. We shall study both plants and animals with the idea of learning how their structure adapts them for the functions which both have in common and shall begin with plants, because, while their functions are similar to those characteristic of animals, their structure is much simpler. The following functions are common to both plants and animals:

Food getting	Excretion
Digestion	Motion
Absorption	Sensation
Assimilation	Reproduction
Respiration	

We know already the names of the principal organs of a plant — the root, stem, leaves, flower, fruit, and seed — and understand, in some measure the functions performed by each. We must also remember the varied surroundings of the plant, the kind of soil, amount of moisture, temperature, insect enemies, and all that goes to make up its conditions of life (environment). In our study we shall start, as the plant starts, with the seed. Then we will follow an account of its growth, and the development, structure, and use of the different plant parts mentioned above.

COLLATERAL READING

General Biology, Sedgwick and Wilson, pp. 20-32; *Applied Biology*, Bigelow, pp. 39-44; *Elementary Biology*, Peabody and Hunt, pp. 29-32; *Essentials of Biology*, Hunter, pp. 31-33; *Botany for Schools*, Atkinson, pp. 33-36; *Botany of Crop Plants*, Robbins, pp. 4-9; *Fundamentals of Botany*, Gager, pp. 14-20; *Plant Anatomy*, Stevens, 1-10; *Plant Physi-*

ology, Duggar, pp. 15-32; *College Botany*, Atkinson, pp. 1-12; *Biology*, Calkins, pp. 6-25; *Encyclopedia Britannica*, articles on "Physiology," "Protoplasm," "Protozoa."

SUMMARY

Protoplasm is the primary, essential living substance of all plants and animals.

A cell is the simplest unit of plant or animal structure. It consists of protoplasm, nucleus, and cell wall.

A tissue is a group of similar cells having a special function.

An organ is a group of various tissues, having a general function.

A system is a group of organs concerned in one or more related functions.

1. Protoplasm.

Derivation: *Protos*, *Plasma*.

Definition.

Composition: C, H, O, N, S, P.

Properties:

- (1) Takes and assimilates food.
- (2) Oxidizes and excretes waste.
- (3) Growth.
- (4) Motion.
- (5) Response to heat, light, etc.
- (6) Reproduction.

2. The cell.

Definition.

Essential parts

Protoplasm.

Cell wall.

Nucleus.

(Diagram)

Function

Any of above properties.

Gives form to cell.

Controls growth and reproduction.

3. Tissue.

Definition.

Examples.

4. Organ.

Definition.

Examples.

5. System.

Definition.

Examples.

6. Relation of Structure to Use.

Similarity of functions.

Difference of structures.

Adaptation or fitness of structure to function.

7. Order for study.

Structure, function, adaptation.

CHAPTER VI

THE STRUCTURE OF SEEDS

Vocabulary

Immature, not fully developed.

Primitive, simple or early form of an organ.

Transmit, carry (similar to transport).

Modified, changed for different use.

It is so common a fact that a seed reproduces the whole plant that the wonder of it is often overlooked. In the seed must exist, alive, all the beginnings for the full-grown plant, together with nourishment to start growth and adequate protection.

The seed, then, is a plant organ which consists of three parts: the immature plant (embryo), stored food, and protective coverings.

Seed Coats. The outer covering of most seeds is called the *testa*, and is usually thick enough to protect from injury by contact, moisture, or insects. It may also have special adaptations for dispersal. A second inner thin coat (tegumen) is present in some seeds.

Since the seed was once a part of the parent plant, it bears a scar on the testa, called the *hilum*, which marks this point of previous attachment. Near this scar is usually visible a tiny opening called the *micropyle*, from two Greek words meaning "little door." This little door has two uses; it lets the pollen enter the seed when it is fertilized (see Chapter XIV), and it lets the young plant out when it begins its growth.

Kernel. Within these coats is the kernel or seed proper. It may consist wholly of the undeveloped plant (embryo); or may have, *outside* the embryo, a store of nourishment called the *endosperm*.

Embryo. If endosperm be present, the embryo may be poorly developed, even showing no sign of its usual parts, as in the orchids. On the other hand, the embryo may be highly developed and show well-defined stem and leaves, as in the bean; for since there is no endosperm in the bean, the plantlet must seek its own nourishment very early. The embryo, or miniature plant, consists of three parts: the *cotyledons*, *plumule*, and *hypocotyl*.

Cotyledons. These are the seed leaves or the first leaves of the plant and, though often not resembling ordinary leaves either in

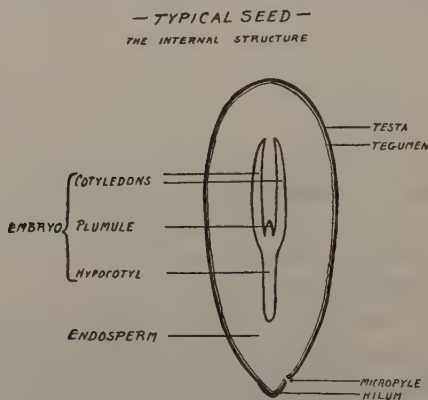


FIG. 4. The internal structure of a typical seed.

appearance or use, still play a very important part in the early growth of the seedling. They may be really leaf-like and come up when the plant begins to grow, forming true green leaves, as in the squash. In this case they are thin and have little stored food, because they get all they need as soon as they rise above the soil. On the other hand the cotyledons may be so well sup-

plied with food that they cannot act as leaves at all, merely coming above ground, giving over their stored food to the growing seedling, and then withering and dropping off, as is the case with most beans. In other cases, such as the pea, the cotyledons are so greatly enlarged with food, that they cannot be lifted from the soil at all, and so supply the plant from their place in the ground below. In cases where the food is stored outside the embryo as the endosperm, the cotyledon often remains in contact with it to digest and transfer food from endosperm to embryo, as is the case in corn.

Not only do the cotyledons vary in size and use (function), but also in number, there being only one in many plants such

as corn and other grasses, lilies, palms, etc., two in many common plants like the bean, squash, apple, and buttercup, and many in pines and other evergreens. So important is this difference that all plants that bear seeds are classified as:

Monocotyledonous (having one cotyledon),
Dicotyledonous (having two cotyledons),
Polycotyledonous (having three or more cotyledons),

and can be placed in one of these three divisions, which also agree, as well, in structure of stem, leaf, and flower.

Plumule. The plumule is that part of the embryo above the cotyledons, from which develops the shoot proper, consisting of stem, leaves, and flowers. It may vary much in size and development. If much food be stored, either in cotyledons or endosperm, the plumule may be small. On the other hand if little food be provided, the plant must early shift for itself, and so the plumule may have several well-formed leaves, wanting only exposure to light to become a self supporting plant.

Hypocotyl. The primitive stem, or all that part of the embryo below the cotyledons, is the hypocotyl. From its *lower* end the root system develops. Upon its *upward* lengthening depends whether the cotyledons shall emerge from the soil when germination takes place.

Endosperm. Though the endosperm is usually present at some stage, it is not found in all seeds when they are mature, since it may be entirely absorbed by the growing embryo, its function of food storage being assumed by the cotyledons. It is, however, very important in many seeds, especially the grains. From its store of starch we derive our bread. Food for the embryo may be stored either in the endosperm or cotyledons. Our laboratory tests show that this stored food consists largely of starch, together with considerable proteid, a little fat or oil, and some mineral matter.

The seed has within itself the miniature plant, or embryo, and all the kinds of nutrients needed for growth except water. This

the seed must get from the soil before it can grow. The growth of a seed is a very wonderful process. Though inactive, dry, and apparently dead the protoplasm is really alive and only awaits favorable conditions for growth to begin.

The insoluble, stored foods must be digested by the embryo, made soluble, united with the water which has been absorbed from the soil, and assimilated, to form all the new kinds of tissue in the growing seedling. It may seem strange to speak of a seed as digesting food, but there is a substance (diastase) in the seed, which digests its food just as truly as the fluids of our stomach digest ours. Here, then, are digestion, absorption, and assimilation going on in the seed as it begins to grow. If the food stuffs in the seed were not stored in a dry and insoluble form, they would dissolve and decay. It is necessary, therefore, if a seed is to keep over winter, that its food must be both dry and insoluble.

EXAMPLES OF SEED STRUCTURE

Each seed differs somewhat from the general description just given; the parts of the embryo may be well or poorly developed; the number of cotyledons may vary; and the endosperm may be lacking altogether.

All that is necessary for a true seed is the embryo, stored food, and protective coverings. These are often very different in structure, to adapt them to various surroundings.

The bean is presented as an example of a dicotyledonous seed without endosperm, while the corn is taken as a type of a monocotyledonous seed in which there is a very large endosperm.

The Bean. External Structure. This familiar seed is usually kidney-shaped or oval in outline, several being borne in a pod, which is the true fruit of the plant.

The testa is usually smooth and may be variously colored; on the concave side it bears a scar (hilum), marking where it was attached to the pod. By means of this attachment it also received nourishment when growing on the parent plant.

Near the hilum is a tiny opening (micropyle), and toward this there sometimes extends a ridge which shows the location of the hypocotyl, which will emerge here on germination.

The tegumen is very thin and often cannot be separated from the testa.

The Bean. Internal Structure. On removing the seed coats, the kernel is seen to consist of the embryo only, the endosperm having been completely absorbed. All the nourishment is now stored in the cotyledons which are large, not at all leaf-like, and contain much proteid and starch.

The hypocotyl is seen as a finger-like projection, fitting into a protective pocket in the seed coats. To it the cotyledons are attached on either side.

By removing one "half" (cotyledon) of the bean, the plumule is exposed, attached to the hypocotyl above the cotyledons and closely packed in between their ends. It is fairly well developed and can be seen to consist of two small leaves, folded over each other.

It will be noted that the upper end of the hypocotyl is the one point where all three parts of the embryo are united. When the cotyledon is removed, a scar showing its place of attachment is left on the side of the hypocotyl.

The pea seed shows a structure similar to that of the bean except that the cotyledons are so enormously swelled with stored

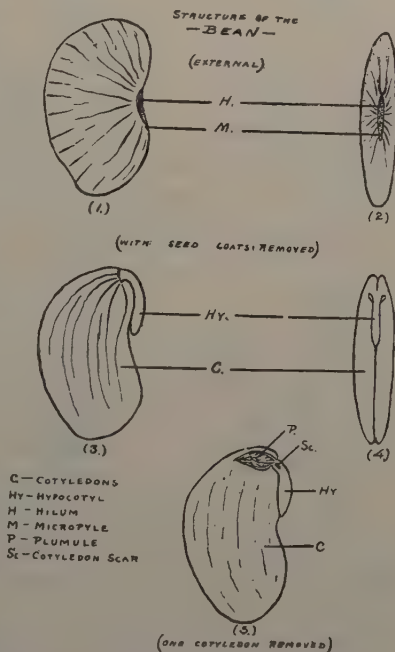


FIG. 5. Structure of bean, exterior; with seed coats removed; with one cotyledon removed.

food that they do not come above ground as do most beans. They remain below and never approach the appearance of leaves.

However, having so much stored food, the plumule of the pea does not need to develop early, so is very small, and even when growth commences, the first leaves of the plumule are mere scales, and do not have much ability to get food. The true leaves do not make their appearance till the food in the cotyledons becomes scant.

FIELD CORN KERNEL
(x4)

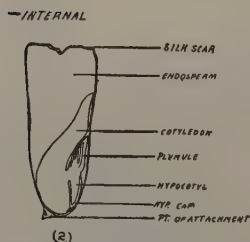
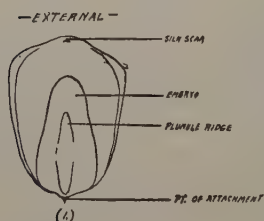


FIG. 6. External and internal structure of corn seed.

Corn. External Structure. The corn seed, as it is usually called, is really a fruit corresponding to the bean pod, rather than to the bean itself. One seed completely fills the fruit, so that the seed coats and fruit coats cannot be distinguished.

As a result of this fact, the hilum and micropyle are covered by the fruit coats and what might be mistaken for the hilum is really the point of attachment of the corn fruit (grain) to the cob.

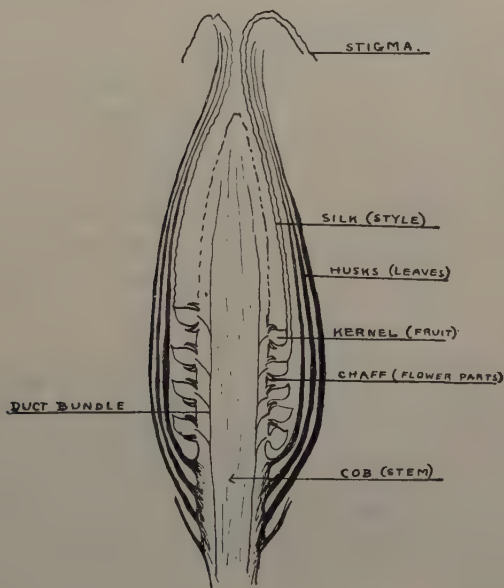
On one side of each grain can be seen a light-colored, oval area, which marks the location of the embryo, visible beneath the coats. On the same side, but at the end opposite the point of attachment, is located a tiny point, the silk scar, where the corn "silk" formerly grew.

Corn. Internal Structure. Internally the corn consists of a large endosperm, containing much starch, proteid, and some oil, and at one side near the point of the grain, a much smaller part, the embryo.

This embryo has but one *cotyledon*, a rather irregular, oval structure, wrapped around the plumule and hypocotyl, and lying in close contact with the endosperm. Its function is to digest and transmit the food stored in the endosperm to the growing seedling. It is a real digestive organ, which secretes, ferments, and makes

the food soluble, just as truly as does an animal's stomach or intestine.

The *hypocotyl* of the corn is a small pointed organ, aimed toward the attached end of the grain, thus leading us to suppose the *micropyle* to be in that region. It is covered with a cap which protects it as it passes through the soil when the root begins to develop.



STRUCTURE OF CORN EAR

FIG. 7. The corn ear is really a spike of fruits closely grown together.

The *plumule* is also protected by a sheath or cap, and consists of several very small leaves rolled, not folded, into a compact "spear" which can safely push upward through the earth.

The cob, on which the kernels are borne, is really a stem of the spike of flowers, each of which produces one kernel. Thus the corn ear will be seen to be a spike of fruits, closely grown together,

and not a single fruit like a bean pod. The chaff around the grains represents some of the outer flower parts while the silk is a portion of the central organ of the flower called the pistil, and its function is to catch and transmit the pollen grains. This will be explained in the chapter on fertilization. The husks are modified leaves developed to protect the corn ear.

<i>Bean</i>	<i>Corn</i>
Has hilum, testa, micropyle	Hilum, etc., covered by fruit coats
Two cotyledons	One cotyledon
Large embryo	Small embryo
No endosperm	Large endosperm
Plumule fairly large	Plumule rather small
Plumule leaves folded	Plumule leaves rolled
The fruit a pod, with many seeds	The fruit a single grain, with one seed

COLLATERAL READING

Lessons in Botany, Atkinson, pp. 2-208; *Natural History of Plants*, K. and O., Vol. I, p. 601; *Natural History of Plants*, Vol. II, p. 450; *Lessons with Plants*, Bailey, pp. 132-133, 252; *Plant Structures*, Coulter, pp. 183-184, 210-214; *Studies on Plant Life*, Atkinson, pp. 158-192; *Practical Botany*, S. and H., p. 343; *Plant Relations*, Coulter, pp. 111-115, 138-140; *Seed Babies* (L), Moreley, entire; *Elementary Studies in Botany*, Coulter, pp. 317-325; *Plant Life and Uses*, Coulter, pp. 325-353; *Experiments in Plants*, Osterhout, pp. 1-68; *Practical Biology*, Smallwood, pp. 259-267; *Cornell Leaflets*, Bul. I., pp. 401-414.

SEED STRUCTURE

Definition of seed.

A plant organ whose function is to reproduce the plant, consisting of:

1. The living miniature plant (embryo).
2. Stored food.
3. Protective coverings.

Structure of seeds.

1. Coats. Function, Protection.

Testa (outer coat).

Hilum (scar on testa). Point of attachment for supply of nourishment.

Micropyle (opening). Entrance of pollen, exit of hypocotyl.

Tegumen (inner coat).

2. Kernel.

Embryo (miniature plant, always present).

(1) Cotyledons (seed leaves)

Development.

- (a) Leaf-like (squash).
- (b) Store food, but come up (bean).
- (c) Store food below ground (pea).
- (d) Digest and absorb from endosperm (corn).

Number.

- (a) Monocotyledonous (one cotyledon) (corn).
- (b) Dicotyledonous (two cotyledons) (bean).
- (c) Polycotyledonous (several) (pine).

(2) Plumule (undeveloped shoot).

Development.

- (a) Small if much stored food.
- (b) Large if little stored food.

(3) Hypocotyl (part below cotyledons).

Development.

- (a) Root from lower end.
- (b) Raises cotyledons if it grows *up*.

Endosperm (stored food, may be lacking).

- (a) Why not always present?
- (b) Use to man.

Food in seeds.

May be stored in cotyledons or endosperm.

Why stored dry and nearly insoluble.

Need of digestion, use of diastase.

TYPES OF SEED STRUCTURE

Bean (Dicot., no endosperm). The pod is the fruit.

External structure.

Shape, color, etc.

Testa.

Hilum, caused by attachment to pod, used to receive nourishment from plant.

Micropyle, used for exit of hypocotyl (see ridge).
used for ingress of pollen (see fertilization).

Tegumen, thin, unimportant.

Internal structure.

Kernel.

No endosperm (what has become of it?).

Cotyledons, two, large and rather thick.
contain starch and proteid.

Hypocotyl, finger shaped. In protective pocket.

Plumule, moderately developed, two plain leaves, veins, etc.

Corn ("Kernel" is the true fruit).

External structure.

Seed coats covered by fruit coats.

Hilum and micropyle hidden.

Items to be located.

Point of attachment to cob, at narrow end.

Embryo mark on side.

Silk scar at broad end.

Internal structure.

Endosperm, large — much stored starch, proteid, oil.

Embryo.

Cotyledon, one, oval, against the endosperm, used to digest and transmit food, has ferments for digestion.

Hypocotyl, protective cap, points to attached end of seed.

Plumule, protective cap, rolled leaves, adapted for piercing soil.

Cob, the stem of flower spike.

Chaff, outer flower parts.

Kernel, the fruit.

Silk, the pistil for catching pollen.

Husks, leaves for protection.

CHAPTER VII

GERMINATION — THE SEED WAKES UP

Vocabulary

Distinct, of separate kinds.

Tolerate, to bear or endure.

External, pertaining to the outside.

Dispersal, the act of scattering, as of seeds.

Emergence, coming out of anything.

Penetration, forcing a way through

The seed is not a thing totally distinct from the parent plant, though it is separated from it. It contains the same protoplasm as the parent plant, with this distinction; its protoplasm is in a condition of rest. The seed is not dead, it is asleep and waits only for favorable conditions to wake into the activity of growth.

Function of the Seed. This resting stage is of two-fold value — it condenses the essential nature of the whole plant within small compass, capable of easy and wide dispersal, and, most important of all, protects the vitality of the embryo so that the seed can withstand periods of drought, cold, heat, or other conditions which would be fatal to the parent plant.

Both dispersal and preservation are steps toward the chief function of the seed, which is to reproduce the plant that is at rest within it. This resumption of active life is called *germination*.

Necessary Conditions for Germination. For the germination of most seeds at least three conditions are required, in amounts varying between wide but definite limits; these are moisture, heat, and air.

There are a few plants whose seed will develop under water while others retain enough of the scant dews of the desert nights to waken the seed into growth. Usually, however, a moderate

water supply is essential, too much causing decay, and too little precluding growth altogether.

As to temperature, a maple seedling will germinate on a cake of ice and many other seeds grow in extreme cold, while a smaller number tolerate high temperatures. The majority, however, germinate most freely between 60° and 80° F.

Air from some source is essential to growth, for seeds, like all living things, must breathe. Many can obtain the needed supply even from the air dissolved in the water in which they may be submerged.

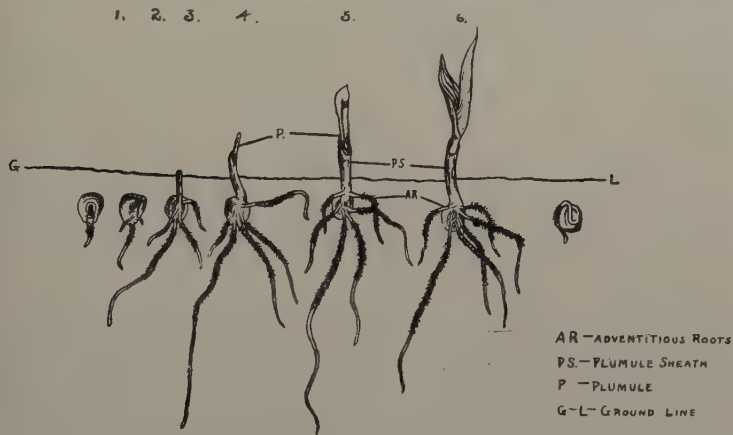
In addition to these external conditions, the embryo must also have a supply of stored food for immediate use while the roots and leaves are developing. This food may be stored in the cotyledons, as in the bean and pea, or outside the embryo, as in the case of the endosperm of the corn and other grains.

Stages in Germination. Germination consists of three steps, emergence from the seed coats, penetration of the soil, and the obtaining of first nourishment.

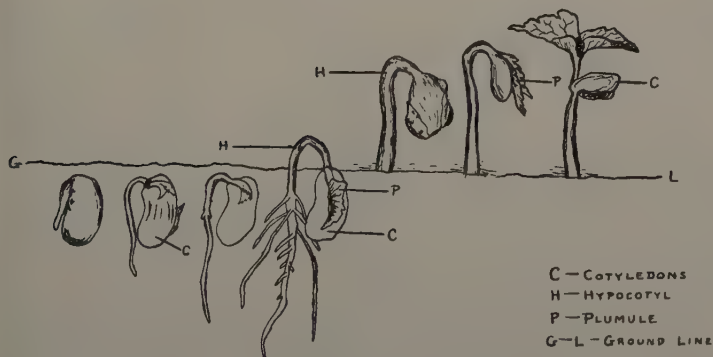
In getting out of the seed coats, the hypocotyl appears first, emerging by way of the micropyle. The rest of the embryo follows by various ingenious schemes, all apparently planned by Nature to enable the seedling to escape uninjured from the testa, on whose protection it has so long depended.

Penetration of the soil may be either from above or from below. When seeds are scattered on the surface of the soil they are enabled to gain a foothold in the earth by various contrivances so that the roots may be sent down into the soil. In the case of buried (planted) seed the process of penetration not only has to do with sending down roots, but the seed must find a way out of the earth, unharmed by its passage. This latter problem is solved most often by the plantlet being started from the seed in an arched position. One end of the arched stem takes hold of the ground and sends out roots, while the other, attached to the wide cotyledons or the delicate plumule leaves, gently pulls these through the ground after the growing arch has broken away to the surface. If forced directly upward these bulky appendages would be stripped off by soil pressure.

This arch may be caused by the weight of the cotyledons and soil (as in the case of the bean), which hold back the bulky end of the plantlet until the stem is strong enough to lift it out of the



—CORN—
STAGES IN GERMINATION



—BEAN—
STAGES IN GERMINATION

ground, or (as in the case of the pea) by the tip of the plumule being held tightly between cotyledons that are not lifted from the ground at all. In the latter case the hold of the cotyledons

weakens after its store of food has been partly exhausted and the plumule is released.

Another method of penetrating the soil is found in the corn and in general by those plants whose first leaves are long and slender. In these cases protection is secured by the leaves being tightly rolled into a point and covered by a cap, so that they pierce the soil directly, thus meeting less resistance and securing safety.

The lifting force of germinating seeds is seldom noticed, but is very great. Masses of earth a hundred times their weight are lifted by our tiny garden seedlings as they come up, forcing their way through the hardest soil.

The last and most important step in germination is the establishment of the young plant in its new environment. In describing this process it is necessary to treat of the development of each part of the embryo by itself.

The hypocotyl first penetrates the testa. Protected by its root cap and directed downward by gravitation, it begins at once the production of the primary root from its lower end. From this, in turn, the whole root system rapidly develops. The only region of growth is just back of the tip, which, protected by the cap, is safely pushed downward into the earth.

The cotyledons, as before explained, may rise above ground if the hypocotyl lengthens upward, or, if not, may remain below. In either case they act as a storage of food for the seedling.

The development of the plumule usually attracts most attention for from it arise the leaves, stem, and, later, the flowers and fruit. It constitutes the shoot of the plant.

The first organ to develop in germination is the root, because the function required by the seedling is the absorption which the root performs. We shall take up the study of this important organ in the next chapter.

Many of the statements made in this, and the preceding chapter, can be proven by simple experiments.

In the first place, the kind of foods stored in the seeds can be proven by the tests described in Chapter IV.

The Necessity of Stored Foods. The necessity of this stored food can be shown by taking a number of well-started seedlings, removing part of the stored food (in cotyledon or endosperm) in some of them, removing it all in others, and leaving still others unharmed. If these seedlings are then placed so that the root can dip into water, by suspending them on a netting over a well-filled glass, their development can be watched.

Several seedlings must be used in each group, lest we draw conclusions from too few instances, or perhaps be misled in case some one seed were abnormal. The conditions of growth must be the same in each case, lest it appear that these varying conditions, and not the loss of stored food, produces the results.

After a few days it will be seen that the whole seeds grow well and rapidly; that those with part of their food removed start more slowly and soon cease growing; while those with all the stored food removed scarcely start at all. This is because of the fact that, until the seedling can develop roots and leaves, it depends solely on this store of food whose removal is shown to have so serious results.

The Digestion of Stored Foods in Seeds. To prove that these food stuffs must be digested before they can be used in germinating plants, corn seeds can be tested for starch and for grape sugar, both before and after germination has started.

Starch is insoluble in cold water, and does not pass readily through the absorbing membranes. Therefore it has to be digested (changed to soluble sugars) before the plant can use it.

This digestive change is accomplished by a substance in the seed, called diastase, which acts somewhat like the digestive fluids in our bodies.

If the corn be tested before germination has begun, much starch and little or no sugar will be found. If it be tested in the same ways, after germination has proceeded for a few days, the reverse will be discovered, as most of the stored starch will have been converted into soluble form, sugar, by the diastase in the cotyledon.

Conditions for Germination. That sufficient heat, air, and moisture are essential conditions for germination, can be proved

by setting up experiments in which several seeds are given similar treatment, except that one of these factors is changed in each.

To prove the necessity of air, place several seeds in each of two bottles, give them moist moss to grow in, and keep in places of similar temperature. Seal one tightly and leave the other open. The results show that the sealed seeds, though they start growth, cease as soon as the air in the bottle is used up, while those in the open bottle grow naturally. In this, as in all experiments, several seeds should be used, so as to prevent drawing a false conclusion from incomplete evidence. Using many seeds and repeating the same experiment increases the accuracy of the test. Emphasis must also be placed upon giving the same conditions, with the one exception, in every case. In the above experiment, if the seeds are not kept in places of similar temperature and moisture, the result of the experiment might be attributed to the differences in these factors and not to the presence or absence of air.

In the same way, it can be proved that seeds require a definite amount of moisture for germination. If none be supplied, or if they be completely covered with water, most seeds will not grow even when the air supply and temperature are properly regulated.

A similar experiment may be used to show the effect of temperature on seed growth. Arrange several seeds in each of three or four bottles; give the same amount of moist moss to grow in, and expose all to free air supply. The one condition to be varied is the temperature. It will be found that those in extreme cold usually do not start growth at all, those in very warm places usually decay, and only those in a moderate temperature germinate naturally.

Suppose some of these last sets of seeds had been given varying amounts of moisture as well as different temperatures, what objection could be raised to the conclusion given?

Experiments like those above in which no air or water or warmth were supplied and in which no results occurred are sometimes called "check" experiments. They are very important, as showing that a certain result will *not* occur without certain conditions.

which is often as necessary as proving that it *will* occur with certain others.

Heat Energy and Carbon Dioxide Set Free. It has been stated in Chapter II that all living things *breathe*. This means that they take in oxygen, which oxidizes their tissues, produces energy, and liberates carbon dioxide as a waste product. We readily realize this in the case of animals but with plants it needs experimental proof.

Provide two large-mouthed bottles each with some moist moss, a vial of lime water, and a stopper through which is inserted an accurate thermometer. In one of them put a handful of soaked seeds and leave the other with none.

As the seeds begin to grow it will be observed that the thermometer in that bottle stands higher than in the one with no seeds, also that the lime water in the seed bottle is *much more milky*, which proves the presence of more carbon dioxide. The lime water in the seedless bottle is *slightly* milky due to the carbon dioxide present in the air. Without this check experiment, nothing could be proved, as the rise of temperature could not be compared and the presence of the carbon dioxide could be attributed to that known to be in the air. Moss was put in both bottles so that all conditions should be the same; if this had not been done, it might have been objected that the presence of the wet moss affected the temperature or gave off carbon dioxide.

While plants do not breathe as actively as animals, still it is thus proved that they do breathe *in the same way* and for the same purpose, namely, to liberate energy for life. The fact that they are less active and need less energy accounts for less evidence of their breathing.

SUMMARY

The seed, a stage of *rest*, not stoppage of life.

Value of this resting stage:

Dispersal	} Steps toward reproduction.
Protection over winter	

Germination (resumption of active growth).

Conditions for germination:

Moisture — Air supply, why necessary — experimental evidence.				
Heat — Stored food	“	“	“	“

Stages in germination:

1. Emergence from seed coats.

Adaptations, Micropyle, Cap on hypocotyl.

2. Penetration of soil.

Adaptations.

By arching method caused by

- (1) Soil pressure (bean).
- (2) Cotyledon pressure (pea).

By direct piercing.

- (1) By rolled plumule with a sheath as in corn.

3. Obtaining nourishment.

- (1) From stored food in cotyledons.

- (2) " " " " endosperm.

- (3) Obtained directly by leaf-like cotyledons (squash), roots from hypocotyl, development of plumule leaves.

NOTE. — If the hypocotyl does not lengthen upward, the cotyledons *must* remain below ground; if it does lengthen the cotyledons "come up." Cotyledons may store food below ground or above; they may become true leaves, or merely act as absorbing organs. (Give an example of each.)

Experiments to show:

1. The kind of food stuffs stored in seeds.
2. The necessity for this stored food.
3. The need of digestion before it can be used.
4. The necessity of air, moisture, and warmth for germination.
5. That growing seedlings produce heat and carbon dioxide (that is, that they breathe).

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CHAPTER VIII

ROOTS — THEIR STRUCTURE AND FUNCTION

Vocabulary

Constitute, to form part of.

Immersed, covered by water.

Adventitious, growing at unusual places.

Retain, to hold.

Epidermis, the outer layer of plant or animal tissues.

Cortex, a spongy layer under the epidermis of roots.

Cambium, region of active growth in root or stem.

The developing seedling consists primarily of the root and the shoot. The latter bears the buds, leaves, flowers, and fruit, while the root, usually hidden and unnoticed in the soil, plays an equally important part in furnishing food and stability to the plant.

Characteristics of Roots. The root differs from the stem in the following points:

Root

Bears no leaves or flowers.
Grows irregularly.
Growth mostly at tip.
Tip protected by cap.
Branching very irregular.
Turns toward gravity.
Branches start internally.

Stem

Bears leaves and flowers.
Grows by definite nodes.
Growth in each internode.
Tip protected by scales.
Branching regular.
Turns away from gravity.
Branches external.

Root System. When a plant is pulled from the soil, the root system is exposed. This may consist of one long central portion, the primary root, from which many secondary branches grow; or it may be a fibrous mass of small roots with no apparent primary,

as in most grasses. In either case the soil particles are closely held to the root by tiny root hairs, the active agents in absorption which are adapted to take up the thin film of water that surrounds all soil particles.

While the form of the root system varies greatly, according to the kind of plant, soil, and climate, yet, in general, all roots have a very similar internal structure, as is shown by a study of sections

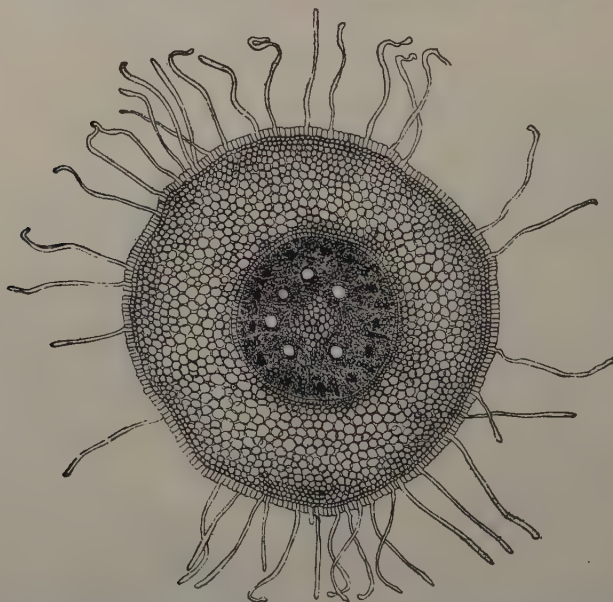


FIG. 8. Section of corn root, showing root hairs formed from elongated epidermal cells. From Atkinson.

of roots in the laboratory. The tips of young roots, split lengthwise and dyed, so as to make their structure plain, should be used for the purpose.

Internal Structure. A typical root has a single outer layer, the *epidermis*, composed of thin-walled, brick-shaped cells, from which extend innumerable outgrowths called root hairs. Beneath the epidermis is a thicker layer of thin-walled, loosely packed, roundish

cells, the *cortex*. This is separated by a boundary layer from the central cylinder which occupies the remainder of the root.

In this central cylinder there are three sorts of tissues which are also found in stems, though differently arranged. They are: (1) wood and ducts, (2) bast, (3) cambium.

The woody tissue is composed of thick-walled, hard cells which give strength to the root but carry little sap, and ducts, which are long, tubular cells, used principally for the transfer of sap upwards toward the stem.

The bast tissue consists of tough, fibrous cells, interspersed with tubular ones. Its function is both to give toughness and to carry sap downwards.

The cambium is the most remarkable tissue in the plant. It consists of thin-walled, very active cells, full of living protoplasm which have the power of rapid growth. In fact, all growth of the plant occurs here, and if the cambium be destroyed, the plant will die.

Since these tissues extend into the stem, where we will hear of them again when we study stem structure, it is important that we should remember their function in the root.

The wood and ducts are generally grouped in four areas near the center, and alternating with them, though outside, is found the bast. The cambium forms a more or less complete ring between the two. This arrangement permits the soil water to reach the ducts without mixing with the digested food brought down from the leaves by the bast.

Around the tip of each growing root and extending up a little way along each side is the protective root cap, composed of loose cells easily rubbed off without allowing injury to the sensitive tip as it pushes through the soil. The region of most active growth, being back of this cap, is protected from injury, as would not be the case if located at the extreme tip.

Function of Root Parts. The function of the epidermis and its root hairs is mainly absorptive. The cortex absorbs, retains, and transfers the soil water: the ducts and bast tubes transfer liquids and air, while fibers in both bast and wood give toughness and

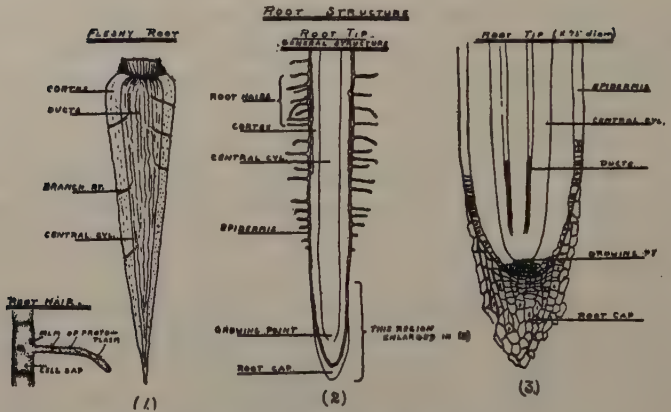


FIG. 9. Root Structure.

Figure 1. A Fleshy Root. — In this diagram can be seen the general region of a typical root, so enlarged by food storage as to be easily visible to the naked eye.

Note especially the ducts in the central cylinder, from which extend secondary branch roots, penetrating the cortex, but not connecting with it. Where they come out they make the tiny cavities characteristic of the surface of a carrot or parsnip.

See also that the stem is mainly connected with the ducts of the central cylinder, and not with the cortex which is mainly an outer layer of stored food.

Figure 2. Root Tip. — Here is shown the general structure of a root tip under low power magnification; — these parts can be seen on any growing root from germinating seed.

Note the protective root cap, and back of that a region without root hairs which includes the growing point. The root hairs, if developed here, would be torn off as growth proceeded, hence begin to grow further back from the tip.

The root hairs are infinitely numerous, and only a few are shown to indicate their comparative length and thinness of wall, and how they develop from epidermal cells.

The central cylinder and cortex can be distinguished in such a root, especially if it be left in a red ink solution till the ducts have begun absorption, which makes the central cylinder much darker than the cortex.

Figure 3. The Root Tip in detail. — This shows the extreme tip, much more highly magnified. The separate cells show plainly, and those near the growing points are particularly full of protoplasm and have large nuclei, showing that they are in active growth.

The loose cells of the cap have few nuclei and are largely dead cells, thrown off as protection to the delicate tip.

The ducts begin to show as thicker rows of cells though not very tubular at this stage.

The epidermis shows plainly as a single layer of cells packed in like bricks.

strength. The most important function, however, is performed by the cambium, which is the region of active growth, and from which both wood and bast are produced.

Functions of Roots as a Whole. *Absorption.* The root, as is evident from its structure, is primarily an absorbing organ, and this function will be taken up at length. However, it has many other uses and is adapted to perform very different duties in different plants.

Fixation. A second use, common to nearly all roots, is that of attaching the plant to the soil, and holding it in an upright position.

Storage. Frequently the root has sufficient bulk to act as a very efficient storage place for foods. This is particularly important for plants that retain life through long winter months.

Propagation. It may happen that enough nourishment is stored so that the plant can send up shoots at various places or even be divided, so reproducing the plant.

Adaptations of Root Form. From the foregoing it is evident that roots must be profoundly varied in structure and form to perform the different functions mentioned. And it must be remembered that not only function, but other factors such as climate, soil, moisture, and exposure, which together make up the plant's environment, affect growth. We shall learn that only so far as a plant is fitted to its environment will it thrive.

Kinds of Roots. The usual place from which roots develop is the lower end of the hypocotyl. Such roots are called *normal roots*. If they grow from other places such as the stem, leaves, or upper part of the hypocotyl, they are called *adventitious roots*.

NORMAL ROOTS

Soil Roots. Of all forms of normal roots, the commonest are the soil roots and these are of many kinds, depending upon what functions they must perform and the character of the soil, moisture, or climate that surrounds them. They in turn may be divided into three general classes.

Fibrous Roots are made up of many fine slender rootlets, giving

large extent of surface for absorption. The roots of the grasses, for instance, are so numerous that they hold the soil together, forming a compact layer called the "turf."

Tap Roots are greatly enlarged primary roots which enable the plant to go deep after water supply and hold firmly in the ground. The thistle, dandelion, burdock, and many more of our worst weeds are thus adapted to make a living under adverse circumstances.

Fleshy Roots are adapted for storage of food stuffs and have the main part greatly thickened, as in the carrot, turnip, and beet. They are generally found in plants which require two seasons to mature their seed and so need stored food to carry them over the winter. In other cases, as the dahlia and sweet potato, the fleshy root is used to reproduce the plant.

Aerial Roots. Some tropical orchids which live attached to trees and never reach the earth at all develop aerial roots. They have a very thick, spongy cortex, which absorbs water from the moist air of the forests.

Aquatic Roots. These are found in a few floating plants such as the duck-weed and water hyacinth. They are usually small, few in number, and lacking in root hairs. They do not need extra surface for absorption because they are surrounded by an abundant water supply.

ADVENTITIOUS ROOTS

Brace Roots. From the stems of corn and many other grasses, develop brace roots, which help to support the slender stems or to raise them again if they are bent down.

Roots for Propagation. In certain plants if the stem lies in contact with the soil for a sufficient length of time, roots will spring from the joints and produce new plants. The stems of various berry bushes can thus be fastened to the earth — "staked down" — and will take root in this way. The new root systems, when sufficiently developed, can be separated from the parent plant to make a new berry bush.

Slips or cuttings from certain plants develop adventitious roots from the stem or leaves and start new plants by this means. Many plants, like the strawberry, send out horizontal stems called "runners" from which adventitious roots develop and produce other individuals.

Climbing Roots. The stems of poison ivy, trumpet creeper, and some other vines grow climbing roots which act chiefly as means of support. These plants have ordinary soil roots, also, for the purpose of absorption.

Parasitic Roots. In a few plants, such as the dodder and mistletoe, parasitic roots develop from the stem, penetrate into the tissue of some other plant, and absorb food from their victim, often causing its death or serious injury. The dodder is parasitic upon clover, golden-rod, and other plants; the mistletoe usually grows upon the oak.

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Characteristics of Roots:

1. No leaves, or flowers.
2. Growth back of tip, not at nodes.
3. Root cap for protection, instead of bud scales.
4. Irregular branching.
5. Turn towards gravity — against light.
6. Internal structure.

Root system consists of

Primary root, or fibrous roots.
 Secondary roots.
 Root hairs.

INTERNAL STRUCTURE

Part	Structure	Function
1. Epidermis Root hairs	Thin, brick shape Thin, tubular, sensitive	Protection Absorption
2. Cortex	Loose, thin, round	Transfer Storage
3. Central cylinder Wood Ducts Bast Cambium	Thick, fibrous Thick, tubular Thin, tubular Delicate, active	Support Transport Transport Growth
4. Root cap	Loose, thin cells	Protection

Region of growth.**Functions of roots:**

Absorption (most roots).

Fixation in soil (most roots).

Storage (carrot, etc.).

Propagation (hop, dahlia, etc.).

Modification of Roots:

Caused by difference in

Function.

Climate.

Soil.

Moisture.

General surroundings.

Exposure.

KINDS OF ROOTS

Normal forms	Examples	Adapted for
1. <i>Soil Roots</i> (a) Fibrous (b) Tap-root (c) Fleshy	Grass Dandelion Carrot	Wide surface Deep water supply Storage
2. <i>Aerial</i>	Orchid	Absorption from air
3. <i>Aquatic</i>	Duck-weed	Absorption from water

ADVENTITIOUS FORMS

1. Brace-roots	Corn	Support
2. Propagation	Strawberry	Reproduction
3. Climbing roots	Poison-ivy	Support, climbing
4. Parasitic	Dodder	Stealing nourishment

Adaptations of Roots:

For penetration of soil:

1. Protective cap.
2. Growing point back of tip, for protection.
3. Root hairs back of tip, for protection.
4. Geotropism and hydrotropism (see next chapter).

For storage:

1. Large size.
2. Protection in soil from cold, drought, and animals.
3. Poisonous or bad tasting, to protect from animals.

For support:

1. Depth and extent of root system.
2. Toughness of wood and bast fibers.
3. Special brace roots, climbing roots, etc.

NOTE. — Look up cypress "knees," and adventitious roots of banyan tree.

CHAPTER IX

ABSORPTION AND OSMOSIS

Vocabulary

Gravitation, the attraction of the earth which draws everything downward.

Successive, one after another.

Aerial, living in the air, as applied to roots.

Hydrotropism, the response of plant parts to water.

Geotropism, the response of plant parts to gravitation.

Osmosis, the diffusion of two liquids or gases through a membrane, the greater flow being toward the denser substance.

Turgescence, the support of plant parts, especially leaves, due to the presence of water in the tissues.

The preceding chapter should have given us a rather definite idea as to the structure of roots, and the names, at least, of some of their functions.

This chapter deals with absorption, the most important function of all, since it is one of the principal ways in which plants obtain food materials. We shall study in detail the adaptations of the root for this fundamental function.

Necessity of Water for Plants. All living matter depends more or less on liquids of various sorts, and the plant, like the animal, has its circulating fluids, bearing nourishment and removing waste, storing food, and supplying oxygen to convert that food into living energy.

From the delicious juices that flavor the peach and sweeten in the heart of the sugar cane, to the bitter milk that flows in the dandelion or lures the unwary to death in the poisonous mushroom, all consist largely of water, absorbed from the soil by the action of the roots.

This absorbed water is of threefold value to the plant. It supplies a very necessary portion of the plant's food, as water

itself and as mineral matter dissolved in that water; it acts as a means of transfer within the plant for the various foods needed in the different parts, much like the blood of animals; and this absorbed water supports many parts of the plant. This latter statement will need some explanation.

Turgescence. When a plant is deprived of water, its leaves droop and we say it wilts. This is due to the fact that, normally, each cell is expanded by the water within it and so is kept in position. If the water be withdrawn, these cells will collapse like an empty balloon, allowing the leaves and plant to droop. If water be supplied before the protoplasm dies, however, the leaves and plant will resume position.

This stiffness of plants, due to presence of water, is called *turgescence* and is very important in supporting the smaller plants whose stems are not stiffened with wood fibers. Nearly all leaves depend on this water pressure for their expansion.

Osmosis. The water to supply these absolutely essential needs comes from the soil, often apparently dry, but always containing at least a little moisture which the plant must obtain if it is to live.

This vastly important root function of absorption depends on a physical process called *osmosis* which may be defined as the mixing or diffusion of two liquids or gases of different densities, through a non-porous membrane — the greater flow being toward the denser substance. Osmosis is one of the most important biologic processes, and upon it depends not only absorption in roots, but all forms of absorption in plant and animal, all digestive processes, excretion, respiration, and assimilation. Wherever a liquid or gas passes through any tissue, osmosis is the acting cause, controlled sometimes by the living protoplasm that lines the cell.

The essentials for osmosis are a dense liquid, a less dense liquid, and the osmotic membrane. In the root the wall of the root hair or epidermal cell acts as the membrane, the cell sap as the denser, and the soil water as the less dense liquid.

Root Hairs. It has been estimated that there may be a total length of a mile in the roots of a corn plant, and alfalfa roots have been found to extend twenty feet deep in dry soil.

For the purpose of absorbing as much as possible, the surface of the active parts of all roots is covered with root hairs. These are outgrowths of the epidermal cell walls and increase the total absorbing surface enormously. They also enable the osmotic membrane to actually touch the film of water, which, even in the driest soils, clings close to the soil grains.

So important are these root hairs that their injury or loss might mean death to the plant, hence they are never borne at the extreme tip of the root, where its growth through the soil would strip them off, but are found a little back from the tip and extending various distances along the younger roots.

As the root grows, new hairs are produced near the tip, to gather moisture from new areas; the upper ones die away; the cortex and epidermis thicken, cease active absorption, and become protective in use. In frequent cases, the root hairs secrete a weak acid which helps in dissolving soil substances and in penetrating hard earth.

The adaptations of root hairs may be summarized as follows:

1. Extent of surface.
2. Thinness of walls.
3. Protection from injury.
4. Location.
5. Close contact with soil grains.
6. Acid secretion.

Geotropism. In order that roots may always grow where they can best absorb food materials, they show a tendency always to grow downward, *i.e.*, toward the earth. This might at first thought be credited to mere weight, but it is evident that stems, though equally heavy, cannot be made to grow down, and that roots, though lighter than the soil, still force their way through it, and cannot be made to grow upward, even though repeatedly started in that direction.

This turning of roots and stems is caused by the attraction of the earth, called gravitation, and this response that plants make to gravitation is called *geotropism* — positive in the case of roots, and negative in the case of stems. Positive geotropism plays an essential part in absorption by causing the roots to penetrate the soil rather than grow in any chance direction.

Hydrotropism. Roots respond similarly to the presence of water, turning toward moisture even at long distances. This tendency, called *hydrotropism*, is very useful, especially if soil water be scant. Vast numbers of fine roots are often found projecting into springs and streams, forcing their way into water pipes or piercing deep into the soil, led by this force that turns them toward the needed moisture.

Selective Absorption. Another fact connected with absorption is, that plants, though growing side by side, take very different matters from the same soil. This apparent impossibility is accomplished by the action of the protoplasm which lines the inner walls of all active cells and has the remarkable power to select, in a considerable degree, what substance the roots shall absorb with the water. This selective absorption, as it is called, accounts for the variety of food substances taken from the same soil by different plants.

Successive Osmosis. All this arrangement for absorption would be useless, were there not some way provided for passing on the absorbed liquids after being taken up by the root hairs. When the outer layer of cells has taken in soil water their contents are diluted, and they become less dense than those next within. Their contents tend to pass to the next inner layer, as the osmotic current is always toward the denser liquid.

This last step removes the newly absorbed soil water from the epidermal cells and leaves them denser again, ready to absorb more soil water from without.

Root Pressure. This process continues inward, from cell to cell, till the ducts are reached, when the liquids rise up through root and stem, causing the uplift which is known as root pressure.

This root pressure is one important cause of the circulation of sap in plants, and is often sufficient to raise the water to heights of one hundred feet or more. But neither this nor any other known cause is equal to the task of lifting water as high as some of our tallest trees, and the method by which that is done is still unknown. This inward osmosis may be reversed by putting salt in the soil. It dissolves in the soil water, makes it denser than the contents of

the cells, which are therefore robbed of their water, since the osmotic flow is toward the liquid of greater density. This fact is often utilized in killing weeds and grass along the sidewalks.

Variations in Osmosis. Osmosis in roots is affected by the temperature and amount of moisture in the soil, being less in cold, dry seasons. Also the presence of organic acids in bogs, or of certain mineral matters in some soils, tends to hinder or prevent the process. Hence it follows that in our cold season, most plants

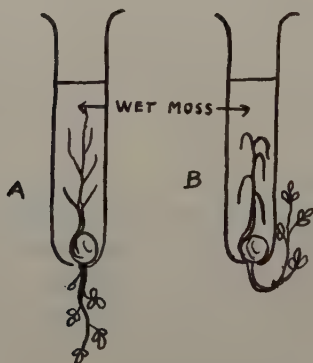
shed their leaves, so that they have less surface from which to evaporate water, because their supply is cut down by the cold.

In the case of both bog and desert plants, many schemes to retain moisture have developed. Though in such different surroundings, both classes of plants have difficulty in absorbing enough water, because of the stoppage of osmosis.

Aerial roots find even greater difficulty in obtaining sufficient water, and many wonderful devices have been developed in the way of hairs to radiate heat, scales to catch water, and enormous, thickened

cortex to retain it when once it is absorbed.

GEOTROPISM



A PLANT INVERTED

**B. ROOTS TURNING DOWN (POS.)
STEM TURNING UP (NEG.)**

FIG. 10. Compare the position of root and of stem in A and B.

EXPERIMENTS WITH ROOTS

To Prove that Roots turn toward Gravitation. If well-started seedlings be inserted in a split cork which is then put into a test tube of water and inverted, it will be found that the upward

pointing root, will soon turn downward at the tip, as will all of its branches. This can be repeated with any kind of seeds. It would not do to infer a general rule from one or two cases.

If a germinating box with well-grown seedlings be turned on its side, the roots will turn down, no matter how often the experiment be changed, thus proving the same thing in another way. Our experience with planting seeds in the garden also is a good experiment in the same line; the root turns down, no matter how the seed is placed.

The same experiments prove that stems turn *away* from gravitation's pull. This is called negative geotropism, and applies to most plant parts except roots. It is evident that what we call "weight" has nothing to do with the direction of either root or stem. The root, though not so heavy as the soil, penetrates it on its way downward, and the stem, despite its weight, turns upward, due to this effect of gravitation on all the living cells.

It might be thought that light had something to do with this change of direction in plant parts. How could it be decided by experiment?

To Prove that Roots Turn toward Moisture. If seeds be planted on the bottom of a coarse sieve which is then filled with wet moss

HYDROTROPISM

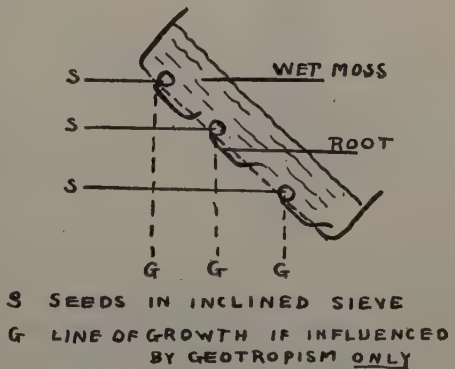


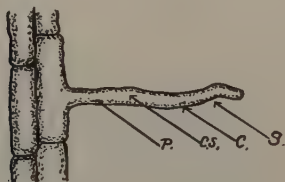
FIG. 11. Note different direction taken by roots, when attracted by moisture.

and tilted at an angle of about 45 degrees, the direction taken by the roots will be different from what might have been expected from the above experiment.

- OSMOSIS -

LABORATORY APPARATUS

DIAGRAM OF ROOT-HAIR



- OSMOSIS -

ESSENTIALS	IN EXPERIMENT	IN ROOT-HAIR
DENSE LIQUID	SUGAR SOLUTION D.	CELL SAP CS
MEMBRANE	OSMOTIC CELL M.	CELL WALL C.
LESS DENSE LIQUID	WATER W.	SOIL WATER S.



FIGS. 12 and 13. Osmosis in root-hair. Laboratory experiment to demonstrate osmosis of liquids.

The roots will start downward at first, directed by gravitation, but when they have penetrated the sieve, they will turn toward it again and reënter the moss in order to find moisture.

This response of roots to moisture is called hydrotropism, and will cause roots to turn toward a water supply if the surroundings be dry, even though they turn partly away from the direct downward line.

To Demonstrate Osmosis. Fill an artificial diffusion shell (such as can be purchased from dealers in laboratory supplies) with molasses and fasten it tightly to a long glass tube by wiring it to a rubber stopper. Insert the shell in a jar of water. Here are the three essentials for osmosis. The shell is the osmotic membrane, the molasses, the dense liquid, and the water, the less dense liquid.

The rise in the tube will be rapid and usually reaches a height of several feet. This illustrates in a way the action of a root hair in causing root pressure, though the root hair, because of its protoplasmic lining, *selects* what will be absorbed, while the apparatus does not.

With the same apparatus, starch or proteid or fat can be placed in the shell, and it will be found that no osmosis goes on, and that they cannot be found in the water outside the diffusion shell. On the other hand, the sugar, peptone, or other *soluble* food stuff, will pass through the membrane, and can be found by test in the water outside.

Not only does plant absorption depend upon osmosis but nearly all the life processes of plants and animals utilize this process in some degree, as will be seen as we proceed.

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HYDROTROPISM

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OSMOSIS

(See references at end of Chapter LIII.)

SUMMARY

Necessity of water.

1. Food.
2. Transportation of food, mineral matter, etc.
Transportation of oxygen.
Transportation of waste.
3. Turgescence.
Meaning of term.
Where it is active.
Importance, in absence of woody support.

Osmosis.

1. Definition.
2. Processes dependent upon osmosis:
Absorption
Assimilation
Digestion
Respiration
Excretion

Essentials for osmosis	In plant	In experiment
Membrane	Root hair or cell walls	Diffusion shell
Dense liquid	Cell sap	Sugar solution
Less dense liquid	Soil water	Water in bottle

(Diagram of root hair — of experiment)

Root hairs.

Structure (see diagram). Location back of tip.
Adaptations for absorption.

1. Large extent of surface.
2. Thin walls for osmosis.
3. Location for protection and large contact with soil.
4. Acid secretion to dissolve mineral matter.

Geotropism. (Contrast action of mere *weight*.)

Definition.

An adaptation for

Penetration of soil.

Obtaining water in soil.

Obtaining nourishment.

Positive in roots.

Negative in stems.

Hydrotropism.

Definition.

Function, reaching water supply.

Selective absorption.

Meaning of term. How controlled.

Successive osmosis.

Meaning of term. Explanation.

Root pressure.

Meaning of term. Reverse osmosis.

Experiments with roots: Geotropism; Hydrotropism.

CHAPTER X

STEMS: THEIR FORMS AND FUNCTIONS

Vocabulary

Node, the point on a stem at which a leaf is attached.

Inter-node, the space between the nodes.

Propagate, to reproduce a plant or animal.

Terminal, at the end.

Lateral, from the side.

Deliberately, intentionally.

The stem is all that portion of the plant body above the root. It differs from the root in the following points:

1. It bears leaves, flowers and fruit.
2. The leaves and branches are borne in regular order, at points called nodes.
3. Growth takes place in the spaces between the nodes (internodes).

Functions. The functions of the stem are:

1. To expose leaves to light and air.
2. To support flowers for pollination.
3. To support fruit for dispersal.
4. To transport liquids up or downward in the plant.
5. To connect the two food-getting organs, roots and leaves.
6. To store food stuffs.
7. To propagate the plant.

Naturally there are many adaptations for these various functions resulting in many forms of stem growth and structure, which modify the whole appearance of the plant.

KINDS OF BRANCHING

Due to Leaf Arrangement. (*Opposite and Alternate.*) The branches of the stem originate as buds, which may be at the end of the stem (terminal), or at the nodes, just above the leaves (lateral). Insomuch as the branches always originate in this way, it follows that if the leaves are opposite on the stem, the branches will be opposite also, and if the leaves are alternately arranged, the branches will arise in the same order.

Examples of opposite arrangement are found in the ash, maple, and horse-chestnut. The alternate type is represented by the elm, oak, beech, and apple.

In either case the chief object of the branch arrangement is to expose the leaves uniformly to light and air. This is accomplished in various ways, depending upon the development of the branch buds, which influences the shape of the plant even more than the leaf arrangement.

Branching Due to Bud Development. Excurrent. If the terminal bud keeps in advance of the lateral buds, a slender, cone-shaped outline results, called the *excurrent* type, such as is shown in the pines and spruces.

Such trees have several advantages:

1. They grow rapidly above their neighbors.
2. Their slender, flexible tops offer little resistance to storms.
3. They can grow close together and still let light down to the lower branches.
4. Their lower branches can bend and shed snow easily.

For these reasons the excurrent type is particularly adapted to cold northern regions, where it is most frequently found.

Deliquescent. If, on the other hand, the lateral buds equal or exceed the terminal ones, the plant assumes a broad spreading outline called the *deliquescent* type as shown by the elm, apple, and oak. This type is very successful in competition with other forms, because, even though it may start late, its broad top shades and kills its neighbors. All plants which grow mixed with these

broad-shouldered and broad-leaved giants, must either get a start before the leaves come in the spring or else must have learned to live with very little light.

Forked Branching. Indefinite Branching. The growth of the terminal bud may be checked by bearing flowers. If so, the branch usually forks in a Y shape, producing round-topped plants, such as the horse-chestnut and magnolia. In some shrubs the terminal bud is unprotected for winter, hence is killed back and thus produces

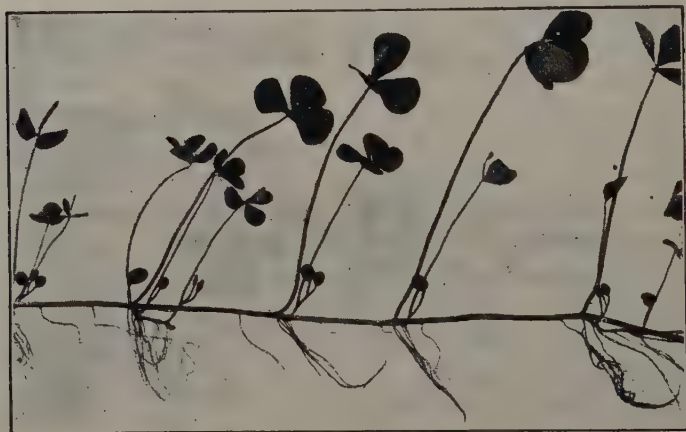


FIG. 14. Creeping stem of the water fern (*Marsilea*). From Atkinson.

a very irregular type of branching, called *indefinite*. This is well illustrated by the sumach.

MODIFICATION OF STEMS

As would be expected, stems are variously adapted to suit different conditions and functions, thus giving rise to many forms.

Shortened Stems. In some plants like the dandelion, the stem is so shortened that the leaves seem to come in a rosette, directly from the top of the root. On this account, the term "stemless" is sometimes applied to such cases. These low-growing plants have many advantages, among which may be mentioned:

1. Escape from grazing animals.
2. Escape from crushing by being stepped on.
3. Crowding away neighbors by the wide, close leaves.
4. Water is retained near the root, by the cover of leaves above.

Creeping Stems. The creeping stem is another type, with common examples, such as the strawberry, in which a plant, though having a weak and slender stem, is, with great economy of wood tissue, enabled to spread its leaves widely. By this habit it also escapes injury from wind, cold, or storms, since it is closely attached to the earth at frequent intervals. Besides, these "runners," as the horizontal branches are called, furnish a valuable means of propagation, since they send out roots at the nodes, and grow even if separated from the parent plant.

Climbing Stems. Many stems succeed in exposing their leaves to the light without producing much more supporting tissue than do the creepers. These are the climbing stems which use supports outside of their own structures to lift themselves into the light. One means of climbing is by twining round some supporting plant, as in case of hops and pole beans. Another similar method is by means of *tendrils*, which are usually leaves reduced to the mere skeleton of veins, as in the grape, wild cucumber, etc.

The coiling of tendrils or twining stems is a curious process, for it frequently seems as though a plant or tendril had started straight for a certain support and deliberately coiled about it. This is not the case though the real process is scarcely less wonderful. The tip of the twiner or the tendril grows unequally on different sides, causing it to swing through the air in circles, as it grows. Thus it has a chance to reach anything within the radius of its swing, which is often several inches.

Having reached a support, the growing point can no longer swing as a whole, but the tip coils about the support as it grows, enabling it to rise as high as its sturdier neighbors. Tendrils also coil between the support and the plant, raising the latter and holding it by a spring which will yield to wind pressure without breaking. This later coil usually reverses midway to avoid twisting the tendril off.

Other methods of climbing are found in plants like the poison ivy, which produces adventitious roots to attach itself, and in the nasturtium, which climbs by hooking its leaf stalks around the supports.

In any case, the climbing habit is very successful, especially in crowded tropical forests where the shade renders necessary some means for a slender plant to reach up into the light to display its leaves. This the climbers do with least possible outlay of wood tissue.

Fleshy Stems. Another modification of stems which frequently occurs is developed for the storage of food. The stem assumes a fleshy form, allowing a large storage volume with little exposure of surface. Such fleshy stems are usually developed underground in order to protect their stored food from animals and cold. Like the fleshy root, these underground stems enable the plants to get an early start in spring and also often propagate the plant very successfully. The simplest underground stem is the *root stock* found in sweet flag and Solomon's seal. Other common forms are the *tuber* of the potato, and the *bulbs* such as the onion, lily, tulip, etc. It may seem hard to think of these as stems, yet if we turn to the first paragraph of this chapter, we will find that they have the characteristics mentioned there and are merely modified to adapt them to special functions.

Bud Structure. A bud is really an undeveloped stem, with the spaces between its leaves greatly shortened, and the leaves themselves very small and closely packed. The chief function of a bud is to keep the growing point of the stem protected from harm and yet ready for rapid growth at the right time. To carry out this purpose, buds have several interesting adaptations.

In the first place, they are usually covered with small leaf-like organs called bud-scales, which overlap as shingles do, and protect the tender shoot from loss of water, mechanical injury, rain, and insect attacks. Often the scales are covered with a sticky gum, which aids it, especially as regards the control of water.

Within the bud, the tiny leaves are frequently packed in a woolly down, which helps protect from injury, especially when the bud is first opening, and may also prevent ill effects from

sudden changes of temperature. The leaves themselves are wonderfully well packed, so as to expose little surface, and economize space; they may be folded, rolled, or coiled, but always in the same way in the same plant.

Buds are always developed either at the end of the stem (terminal), or just above the leaves (lateral). Their growth consists of three stages, the opening of the scales, the lengthening of the stem, and the expansion of the leaves. The scales fall off during this process, leaving the bud-scale scars to mark their former place. As most buds begin growth in the spring, these rings of scars mark the beginning of each year's growth. The age of the stem can thus be calculated as long as the scars show.

SUMMARY

Definition.

Characteristics of stem

- Bears leaves, flowers, fruit.
- Leaves and branches at nodes.
- Growth between nodes.

Functions:

- Support { of leaves for light and air.
 of flowers for pollination.
 of fruits for dispersal.

Transportation of liquids between root and leaf

Storage of food.

Propagation.

Kinds of Branching:

Object of branch arrangement in general.

Branching due to leaf arrangement.

Opposite. (Ex.)

Alternate. (Ex.)

Branching due to bud development.

1. Excurrent. (Ex.)

Shape of tree. Cause.

Advantages:

Rapid growth in height.

Little storm resistance.

Can grow closely.

Shed snow readily.

2. Deliquescent. (Ex.)

Shape of tree. Cause.

Advantages, shades out its neighbors.

Few can grow together.

3. Forked. (Ex.)
4. Indefinite. (Ex.)

Modification of Stems:

1. Shortened stems. (Ex.)
Advantages, escape grazing animals, or crushing.
Crowd away neighbors.
Retain water at roots.
2. Creeping stems. (Ex.)
Advantages, widespread, little wood.
Escape injury.
Propagation.
3. Climbing stems.
Advantages, escape from shade conditions.
Expose leaves with little wood tissue.
Means of climbing:
Twining. (Ex.) Method of operation.
Tendrils. (Ex.) Method of operation.
Adventitious roots. (Ex.)
Leaf stalks. (Ex.)
4. Fleshy stems. (Ex.)
Advantages: Safe storage, early start, propagation.

Buds.

- Definition.
- Function.
- Adaptations:
 - Scales.
 - Gum or hairs.
 - Woolly packing.
 - Leaf arrangement.
- Location.
- Manner of growth.
- Bud scale scars.

COLLATERAL READING

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CHAPTER XI

STEM STRUCTURE

Vocabulary

Lenticels, openings in the bark for passage of air and water vapor.

Radiating, extending out from the center.

Fabric, woven material such as cloth.

Perennial, living year after year.

Dicotyledonous, plants having two cotyledons. (Dicots.)

Monocotyledonous, plants having one cotyledon. (Monocots.)

EXTERNAL STRUCTURE

The external structure of all ordinary stems, though varying greatly, has some points in common. It will be seen that there is an outer covering, the epidermis or bark, which protects from injury by storm and insects and prevents undue loss of water, as a result of drought or cold.

Lenticels. Through this bark are openings (lenticels) which permit a regulated escape of water-vapor, and also admit air.

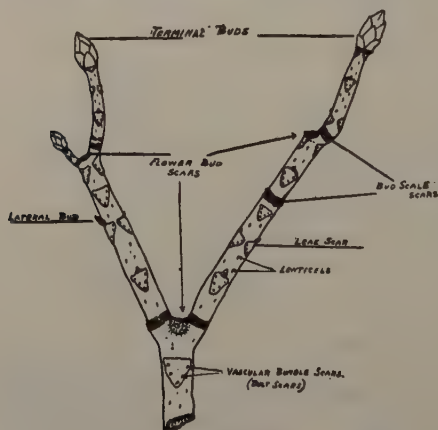
Leaf Scars. On the bark will be found scars left by leaves of preceding seasons, varying in location according as the leaves were opposite or alternate, and having above them the buds for the coming year's branches. On these scars will be found dots marking the severed ends of the ducts, which can be traced into the stem and found to extend to the roots. Over these scars is a water-proof coat (abscission layer) which formed *before* the leaf fell to protect the plant against the loss of so many leaves and consequent bleeding from thousands of tiny wounds.

Flower-bud and Fruit Scars. It frequently happens that the bearing of a flower or fruit makes a scar differing from those made

by falling leaves. These are especially plain in the horse-chestnut. A flower-bud always ends the growth of the stem that bore it, hence further growth is by lateral buds which produce a forked type of branching, where the flower was borne.

Bud-scale Scars. At various places on the stem are rings of small scars caused by the bud-scales of previous years which were

shed as spring activity commenced, thus marking the first growth of each year. Other markings are frequently met with, caused by injuries from weather or insects. These the plant has met by thickening its bark.



EXTERNAL STRUCTURE
— OF A STEM —
(HORSE-CHESTNUT)

FIG. 15. Stem showing lenticels and different kinds of buds and scars.

INTERNAL STRUCTURE

On cutting across the stem of any common tree, the general internal structure will be shown, in most cases, without the use of lenses. Three regions can be dis-

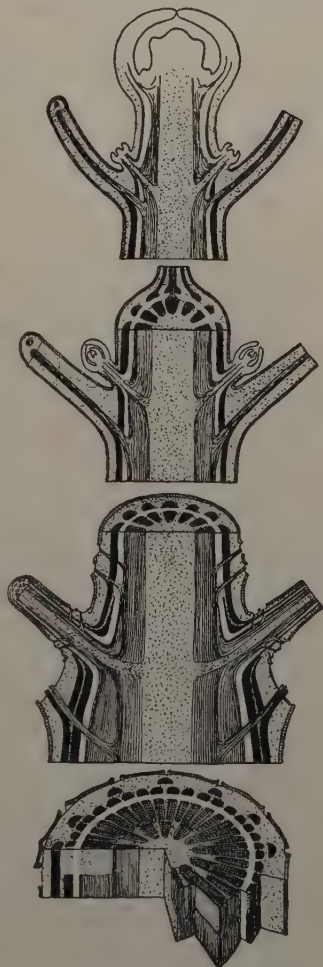
tinguished easily — bark, wood, and pith. A closer inspection reveals a fourth, between bark and wood. This is the cambium, a thin, light-colored zone of very juicy cells, which here, as in the root, produces all the other tissues.

Wood. The wood will be seen to be arranged in circles, “annual rings” of alternately coarse and fine tissue, the ducts, and wood fibers, while radiating from the pith and extending across these rings are the pith rays that connect pith and bark.

Bark. The bark will repay a closer scrutiny with a hand lens and will be found to consist of an outer epidermal layer, often variously thickened and roughened by growth; next, the

“green layer” (cortex), and within this the bast fibers and tubes, which transfer liquids downward and give toughness to the bark.

FIG. 16. Diagram of maple stem showing the development of wood and bark through first and second years. At the tip is a mass of living formative material (shown unshaded) from the sides of which arise protrusions that become leaves. Also arising from the formative region, just above the base of the very young leaves, are protrusions which develop into formative regions like those of the main tip, and, as growing-point, produce leaf-bearing branches of the main stem. In the center, around the axis, the formative material as it grows older becomes *pith* (shown as dotted) and this pith is continuous with that of the branches. The surface becomes changed into a skin or *epidermis* (coarse shading) covering both stem and leaves. Parts of the formative material between the epidermis and the pith become variously hardened into bundles of fibrous material; around the central pith arise strands of *wood* (fine shading); near the epidermis arise corresponding strands of *bast* (shown by black) surrounded by more or less pith-like material which may become green or corky, called *cortex* (shown dotted like the pith); and between the rings of wood and bark is a layer of formative material which is continuous with the tip and is called the *cambium*. From this cambium in successive years new wood is added to that within and new bark to that on its outer side, and thus both wood and bark increase in thickness by annual layers. But on the outside the epidermis, and then the older bark, is pushed off or worn away so that the total thickness of the bark is limited. Both wood and bark are continued into the leaves, but not the cambium. The strands of wood and those of the bark are so connected as to form a sort of network through the meshes of which extend radially the plates of pith called *pith-rays*.



From Sargent.

FUNCTIONS OF STEM TISSUES

The tissues in order from without are the epidermis, cortex, bast fibers (hard bast), bast tubes (soft bast), cambium, wood, ducts, pith, and pith rays from center to cortex. Each of these layers has its definite functions, several of which have been stated.

Epidermis. The outer layer, or epidermis, is largely protective and in several ways. Its thickness guards against injury from wind, weather, and attacks of insects. It does not allow loss of water, except at the lenticels, thus preventing undue drying of the delicate tissues beneath. It also keeps out the spores of parasitic fungi that might otherwise find entrance and destroy the plant.

Cortex. Under the epidermis is the cortex, whose function is to help prepare starch food for the plant, much as do the leaves.

Bast Fibers. The bast fibers give toughness to the bark, sometimes helping support the stem. Man has taken advantage of the fiber strength of hemp and flax (look up) to make fabrics.

Bast Tubes. The soft bast conveys food prepared by leaves downward to various places where it is used or stored.

Cambium. The growth function of the cambium cannot be too often mentioned, as from it, by a complicated process of cell division, bark tissues on the outside and wood and ducts within are formed.

Ducts. The ducts transfer liquids up and air down in the stem, and add their strength to the woody portions, whose fibers are the chief support of the stems of all larger plants. Together they make up the bulk of the stem tissue.

Wood Fibers. Both the wood fibers and ducts are arranged in very definite circles, called *annual rings* because usually each ring marks a year's growth. These rings are caused by the cambium which produces larger ducts and more of them in the spring when the sap is flowing than later, when more wood fiber is produced. In the winter, the growth practically stops, only to begin the following spring with a layer of large ducts again, thus marking, by these successive rings of tissue, the seasons' changes.

Pith. The pith may be a minute remnant of the formative tissue, or a larger storage place for foods and the pith rays serve as cross channel for liquids to follow in their circulation in the stem.

So we have one protective region, the epidermis; one digestive region, the cortex; one formative region, the cambium; one storage region, the pith. The ducts, soft bast, and pith rays are the channels for circulation of fluids while the wood and bast fibers are for strength and support.

Grafting. The remarkable ability of the cambium cells to grow and produce new tissues is utilized in grafting. Grafting consists in bringing into close contact the cambium layer of a small active twig with that of the tree upon which it is to grow. This may be done by splitting the stem, and inserting the fresh-cut twig, or by raising the bark and inserting an active budded twig beneath it, with the cambium layers in contact. The wound is then protected by wax and growth between the two cambium layers soon unites the new stem with the old.

The cambium also provides for the healing of injuries and the covering of scars where branches are cut off. New tissue forms at the edges of the wound and gradually covers the whole area, provided that spores and bacteria do not first cause decay of the exposed surface. To prevent this, cut or injured surfaces should always be tarred or painted to kill and keep out bacteria, while new tissue is growing. If decay has begun the rotted wood must be cleanly removed, the cavity sterilized with tar and filled with cement. The cambium growth will now extend the tissue inward from the edges and often cover the scar, filling and all.

In rare instances two limbs, or even two separate trees of the same kind, will chafe together in the wind, till the cambium is exposed in both. Then if undisturbed, an automatic graft may occur and a curious condition will develop, in which the two trees will continue to grow firmly together.

Other Kinds of Stem Structure. In the chapter on seed structure it was stated that plants whose seeds had two cotyledons (dicotyledonous plants) had stems that differed from plants whose seeds had one cotyledon (monocotyledonous). The stem just

described is such a one as would be found in a dicotyledonous plant. The monocotyledonous stem differs in so many ways that

it requires special consideration.

Corn Stems. The common corn stalk is a good example of the monocotyledonous type of stem. If we cut a section across it, we find the tissues very differently arranged from those in the dicotyledonous stem, just discussed. The monocotyledon, in place of a bark of several layers, has a *rind* of only one kind of tissue — thick-walled, hard cells whose function is mainly to support the plant. The wood, cambium, and bast tissues are grouped in numerous “*vascular bundles*,” which, instead of being in definite rings, are scattered through the stem, the larger and older ones toward the center and smaller and younger ones near the edge. The *cambium* in monocotyledons ceases to build new tissue, after a time. Hence the stem does not continue to increase in diameter as does the dicotyledonous stem, but produces tall slender plants like corn, grasses, bamboos, and palm trees. The bulk of the stem consists of the soft thin-walled *pith*, instead of wood and ducts, so that the



FIG. 17. Diagram of palm stem (monocot). From Sargent.

structure is almost reversed in these two types of stems although the same tissues are present. As one result of this striking dif-

ference we obtain many of our wood products from the dicotyledonous stems, while the monocotyledonous, having little wood and much pith for storage, provide us with foods such as hay and grain, sugar-cane, and starch.

Do not think that the monocotyledonous stem is weak because it has so little wood tissue — the case is quite the contrary as you may prove for yourself.

Select a tall grass stem, such as timothy or rye. Measure its height and its diameter. How many times its thickness is the height? Suppose it were a tree one foot in diameter how tall would it be? Compare this with the actual height of trees. Figure this out and you will have more respect for the strength of the grass stem, as well as for the “sturdy oak.”

Polycotyledonous Stems. Seeds having several cotyledons (polycotyledonous) have a woody stem with annual rings, but differing in other ways from the two preceding types. We shall not take up its structure in detail; pines, spruces and all evergreen trees belong to this last group and their resinous wood furnishes us with our best lumber.

Not only are their stems of great strength, but some of them are the largest and oldest living things in the world. The Big Trees (Sequoia) of California are the oldest, even among trees. One of these ancient giants, the “General Sherman Tree,” is nearly four thousand years old, 279 feet high, and 36 feet in diameter.

To put it another way, it was a flourishing sapling, twenty or thirty feet high when the Exodus of Israel and the Trojan wars took place. It was a thousand years old at the time of Solomon and two thousand at the birth of Christ. All our European and American history are but events of yesterday to this patriarch of

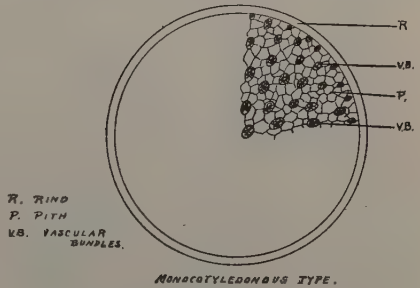


FIG. 18. Cross section of typical monocotyledonous stem.



FIG. 19. *Sequoia Washingtoniana* (Bureau Forestry, U. S. Dept. Agr.)
From Atkinson.

the organic world, which now towers higher than a twenty-story building and is still growing. Some animals, such as the elephant, may live two hundred years, but even these, or man, with his three



Courtesy of the American Museum of Natural History.

FIG. 20. Section of one of the big trees of California, the "Mark Twain," 16 ft. in diameter, and 1341 years old.

score years and ten, are the merest infants beside such ancient inhabitants of the vegetable world.

This illustrates a fact which is often overlooked, that perennial plants really have no limit of growth, as do animals, but keep on

STEM STRUCTURE

External Features	Structure	Function
Bark		Protection
Lenticels	Spongy openings	Let out water vapor Admit air
Scars left by		
1. Leaves showing	Cut ends of ducts	Prevent loss of sap
Duct scars	Water proof cover	Mark year's growth
Abscission layer	Formed in spring	Cause branch to fork
2. Bud scales	Usually terminal	
3. Flowers and fruit		

Internal Features

1. Bark		
Epidermis	Thin if young, corky in older stems	Protect from insects, fungi and weather Retain water
Cortex	Thin walled, soft cells	Food making and digestion
Bast fibers	Thick and tough	Strength
Bast tubes	Long, tubular cells	Downward transfer
2. Cambium	Very active, protoplasm	Growth
3. Wood region		
Wood fibers	Thick walled, stiff	Support
Ducts	Thick walled, tubular	Upward transfer
4. Pith	Thin walled, weak	Storage
Pith rays		Cross transfer

Comparison of Dicot and Monocot Stems

Features of each	Dicot	Monocot
Outer layer	Bark of several tissues	Rind of one tissue
Vascular bundles	In regular rings	Scattered
Bulk of stem	Wood	Pith
Supported by	Wood region	Rind
Cambium	Permanent	Not permanent
Growth	Continuous in height and thickness	In height only
Use	For lumber, fuel, etc.	For food stored
Usual shape	Thick	Tall, slender
Examples	Broad-leaved trees and common plants	Grasses, lilies, palms, sugar-cane, etc.

increasing slowly in size for indefinite periods, while animals reach a maximum size and grow no larger, no matter how old they become. The reason is probably that in plants, little energy is required, hence little food is used in oxidation and more is left for additional growth, whereas in animals, which use more energy, a point is reached, where the nutritive processes are just balanced by oxidation and further growth ceases. As soon as the destructive processes exceed the constructive, old age enters and finally death itself.

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CHAPTER XII

LEAVES AND LEAF STRUCTURE

Vocabulary

Surplus, an extra supply.

Originate, to begin.

Accumulated, collected together.

Excessive, too great.

Communicate, to connect.

Stomates, openings in leaf epidermis to admit air and let out water vapor.

Heliotropism, the response of plant parts to light.

Chlorophyll, the green coloring matter of plants.

Transpiration, the passing off of excess water from plants.

Vascular, composed of "vessels" or tubular cells, such as the vascular bundles of ducts in stem and leaf.

Parenchyma, thin-walled, spongy plant tissue.

Leaf Functions. The *leaf* is one of the most remarkable and important parts of the plant. Within it are performed more life functions than in any other plant or animal organ. Its chief and unique function is the manufacture of starch out of water from the soil and carbon dioxide from the air. Animals cannot prepare starch from these two compounds and must therefore depend upon plants for their supply. Not only does it prepare, but it also digests and assimilates food, sending its surplus, by way of the veins (duct bundles), to all living parts of the plant. Furthermore, the leaves are constructed so as to admit air for oxidation, and to throw off carbon dioxide (respiration). Excretion of water (transpiration) and of other wastes is another function of these versatile organs. They also possess in some degree the powers of motion and reproduction. Food making, digestion, assimilation, respiration, excretion, motion, reproduction, — these are all the functions that any living thing can perform. One entirely, and all to some extent, are performed in the leaf.

GENERAL STRUCTURE OF LEAVES

A leaf usually consists of a thin flattened portion (the *blade*) stiffened by a framework of veins which are really bundles of ducts connecting with those in the stem. Usually the blade is attached to the stem and held out into the light by a stalk (the *petiole*). Its point of attachment is called the *node* of the stem, above which all branch buds originate. The *veins* may form a network throughout the leaf or may be almost parallel (grass). There may be one large midvein with branches like a feather (elm), or several veins of equal size may spread from the petiole like the fingers of your hand (maple), but whatever the arrangement, their function is to support the blade and transfer the liquids concerned in the various leaf processes.

Leaf Forms. The outline of a leaf depends largely upon the arrangement of its veins. If netted veined the leaves are usually broad, notched, or lobed; while if the veins are parallel they are usually long and slender. The forms of the leaves are almost as various as the kinds of plants; some having regular or entire edges (lily), others notched, lobed, or finely divided (elm, maple, carrot), while still others are composed of separate leaflets (pea, horse chestnut), and so are called compound.

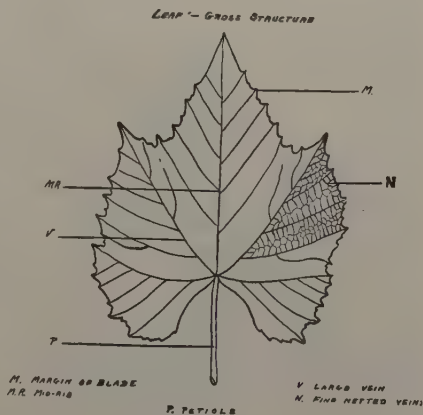


FIG. 21. Structure of leaf — exterior.

ADAPTATIONS FOR EXPOSURE.

Form. These different-shaped leaves are developed with but one end in view—the complete exposure of the leaf tissues to

light and air, on both of which all the activities of the leaf depend.

Arrangement. Not only are leaves adapted by their shape for this exposure, but by their arrangement on the stem. Look at a tree from above or at a house plant from the "window side" and observe that the branches and leaf stems (petioles) have so ex-



FIG. 22. Sunflower with young head turned to the morning sun. From Atkinson.

tended and twisted themselves, that each leaf is exposed and very few cast any shade upon their neighbors.

Heliotropism. Another adaptation for leaf exposure is their ability to constantly turn themselves toward the light. This is an every day observation, but no one can explain just *how* they do it. The process is called *heliotropism* (which means sun turning), and is very essential to the work of

the leaves. Roots turn *from* light (*negative heliotropism*) while this response made by leaves *toward* the light is termed *positive heliotropism*.

Modified Leaves. Like roots, leaves are often modified to perform special functions: They may be reduced to mere tendrils for climbing (pea) or they may develop as thorns for protection (barberry). They may thicken up with stored nourishment and even reproduce the plant (live-for-ever), or most curious of all, may develop into traps for insects (sundew and pitcher-plant).

Fall of Leaves. Most plants of temperate climates shed their leaves, either all at once in autumn (maples, elms) or a few at a time the year round (pines and spruces). They do this so they may rid themselves of waste mineral matter that has accumulated

and, in the case of the broad-leaved plants, this shedding also comes because it is necessary to reduce the exposed surface so that too much water may not be evaporated in the winter, when the roots can supply but little. Of course one can see another reason for plants that grow in climates where snow prevails during the winter. The weight of snow accumulated by the leaves would tend to break the plant down.

In the case of the pines with their slender needles this reason does not apply.

The color changes of autumn are not due to frost entirely, but may be caused by anything which stops the activity of the plant. The beautiful yellows and reds that make our autumn a blaze of glory act as a protection to the sensitive green substance of the leaves, which is being withdrawn and stored for use another year.

Before the leaves of a plant fall there is formed at each leaf base a waterproof layer (abscission layer) which prevents the loss of sap after the leaf is gone.

The enormous amount of ashes left when the leaves are burned gives some idea of the amount of unused mineral matter which the plant had stored there, and incidentally reminds us that plant ashes, whether from stems or leaves, are useful food materials for plants and ought to be put back on the soil for use another year.

MINUTE STRUCTURE OF LEAVES

The chief function of the leaf is the manufacture of food materials. To understand this, a thorough study of the minute structure is necessary.



FIG. 23. The same plant at sundown showing the head turned to the west. From Atkinson.

If the blade of a leaf be cut across and studied with a microscope, the following tissues may be observed. Mentioned in order from the upper surface they are:

1. The cuticle (sometimes lacking).
2. The upper epidermis.
3. The palisade cells.
4. The spongy layer (traversed by veins).
5. The air spaces.
6. The lower epidermis (penetrated by stomates).

The Upper Epidermis. This usually consists of a single layer of cells often very irregular, as seen from above, but brick shaped when viewed in cross section. There are few stomates in the upper epidermis, since they would be exposed to dust and rain. The function of the upper epidermis is to prevent loss of water. To aid in this, it is sometimes covered by a waxy layer, called the *cuticle*, as in ivy, cabbage, and other leaves that shed water in drops. A second function of these epidermal cells may be to act as lenses and concentrate the sunlight upon the inner parts of the leaf. The fact that their upper and lower surfaces are curved like a lens, leads to this supposition.

The Palisade Layer. Next beneath the upper epidermis is the palisade layer. It consists of long narrow cells, placed endwise, at right angles to the surface of the leaf. Within these cells is found the *chlorophyll*, which is the green coloring matter of all plants. As you will learn later, it is very sensitive to light and these long cells permit the chlorophyll grains to move to the upper ends if the light be dim, or to retreat to the long side walls if the light is too strong.

The function of the palisade layer, then, is to regulate the exposure of chlorophyll to light, and to carry on starch making.

The Spongy Layer. Beneath the palisade layer is a spongy layer which consists of thin-walled cells and air spaces, and is penetrated in all directions by veins (duct bundles). The spongy cells are roundish, irregular, and loosely packed, thin walled, and full of protoplasm and chlorophyll. In them, as in the palisade

layer, starch making and all the other leaf functions are carried on. The passing off of water to the air spaces is part of its work. The air spaces are usually large, irregular cavities among the spongy cells. They open through the lower epidermis by way of the stomates, their function being to receive water vapor from the spongy cells and to pass it out through these openings. They also permit oxygen and carbon dioxide to pass to all the cells of the spongy layer. They are very important, since through them food making, respiration, and transpiration go on. They occupy about three-fourths of the bulk of the spongy layer. The veins or duct bundles are scattered through the spongy layer transporting water and food stuffs and supporting the blade of the leaf.

The Lower Epidermis. Like the upper, the lower epidermis usually has but one layer of cells. Through it open many stomates which regulate the passage of air and water vapor to and from the inside of the leaf.

The Stomates. These have been referred to as openings through the epidermis. They are minute slit-like holes, about one-twentieth as wide as the thickness of this paper. On each side of the slit is an oval guard cell which regulates the opening and closing of the stomate. Controlled by the needs of the plant, the stomates open when there is an excess of water to be passed off, and close in a drought. They open when carbon dioxide is required for starch making or air for breathing, and close when either process stops, thus regulating, in a remarkable degree, the activities of the leaf. The function of the stomates is threefold,

1. To admit carbon dioxide for starch making.
2. To regulate transpiration of water vapor.
3. To admit oxygen and liberate carbon dioxide in respiration.

However, this elaborate mechanism would be of little use were it not for the extensive system of air spaces in the spongy tissue of the leaf into which the stomates open, and by means of which all parts may have access to air for starch making, respiration, and transpiration. Their number may vary from 60,000 to 450,000 per square inch and is usually greatest on the lower surface where they are best protected from dust and rain. Floating leaves have

all their stomates on the upper surface. In vertical leaves they are evenly distributed.

Chlorophyll. The green coloring matter of plants is the most important part of the leaf. Practically the whole function of the

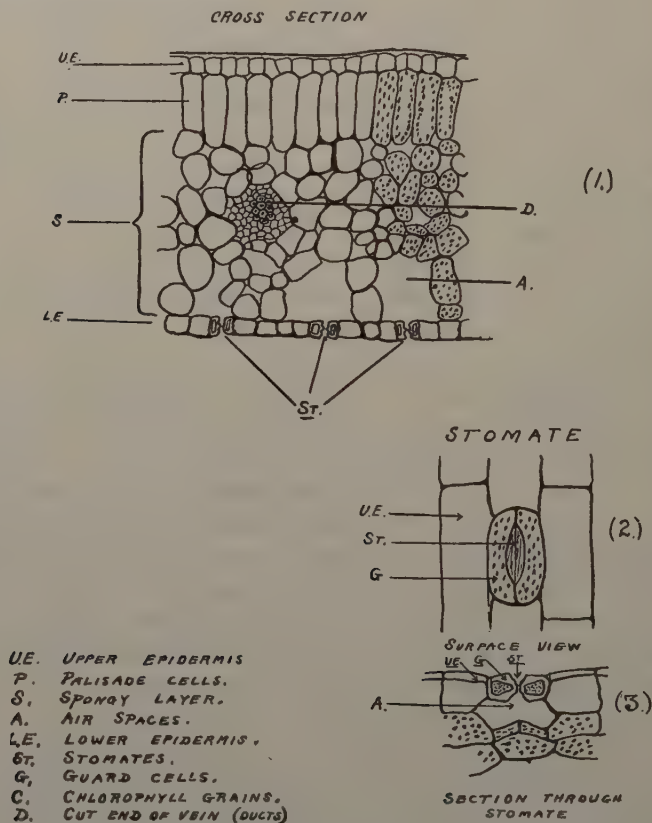


FIG. 24. Leaf Structure.

rest of the leaf is to expose the chlorophyll to light and provide it with materials upon which to work. Chlorophyll is composed of nearly all the elements we find in any plant tissue, but is especially rich in iron compounds which give it its green color. It is

found in the form of very minute particles called chlorophyll grains, or chloroplasts, which seem to consist of active protoplasm combined with the green chlorophyll. This is the substance which performs the essential function of the leaves. It is found mainly in the palisade cells and spongy layer. The former are arranged to regulate its exposure to light, and the latter to provide it with carbon dioxide and water to use in starch making. We shall devote the next chapter to the way in which it does its work. For the present, think of chlorophyll as occurring in the form of active, green grains, found in all green parts of plants and very essential to their growth.

SUMMARY

Functions:

1. Starch making.
2. Digestion and assimilation.
3. Respiration.
4. Excretion.
5. Reproduction.

General structure:

1. Blade.
2. Petiole (leaf stalk) attached at *nodes*.
3. Veins (duct bundles).
 Functions, support and transportation.
 Arrangement:
 Parallel (grasses).
 Netted:
 Feather veined (elm).
 Finger veined (maple).
4. Outline.
 Irregular margin in netted veined leaves.
 Regular margin in parallel veined leaves.

Adaptation for exposure to light and air:

1. Shape, so as to let light through to others.
2. Arrangement, opposite or alternate.
3. Heliotropism.
 Positive in leaves and flowers.
 Negative in roots.

Modified leaves, as

1. Tendrils, for climbing (pea).
2. Thorns for protection (barberry).
3. Thickened, for storage (cactus).
4. Traps, for catching insects (sun-dew).

Fall of Leaves:

1. Reasons.
 - Remove waste mineral salts.
 - Lessen exposure to storms.
 - Reduce surface for transpiration.
2. Cause of coloration. Function.
3. Abscission layer.

SUMMARY OF MINUTE STRUCTURE OF LEAVES

1. Upper Epidermis.
 - Structure: One layer, brick-shaped cells, few stomates.
 - Cuticle sometimes present.
 - Function: Prevent loss of water.
 - Concentrates sunlight on chlorophyll.
2. Palisade Layer.
 - Structure: Narrow, perpendicular cells. Contain chlorophyll.
 - Function: Regulate exposure of chlorophyll.
3. Spongy Layer.
 - (a) Spongy cells.
 - Structure: Thin, irregular, loose, active.
 - Function: Starch making and transpiration.
 - (b) Air spaces.
 - Structure: Large irregular cavities.
 - Function: Transpiration, air supply.
 - (c) Veins.
 - Structure: Bundles of ducts and wood fibers.
 - Function: Transportation and support.
4. Lower Epidermis.
 - Structure: Single layer of cells, many stomates.
 - Function: Regulation of water and air supply via stomates.
5. Stomates.
 - Structure: Slit-like opening and guard cells.
 - Function: Regulate transpiration, supply of carbon dioxide and of oxygen.
 - Distribution: Lower epidermis usually very numerous.
6. Chlorophyll.
 - Structure: Active green grains, rich in iron compounds.
 - Function: Photosynthesis or starch making.
 - Distribution: Palisade cells and spongy layer.

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HELIOtropISM

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STOMATA

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LEAF ARRANGEMENT

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MINUTE STRUCTURE

Parts	Structure	Function
Epidermis (upper and lower)	One layer; irregular cells	Prevents loss of water
Stomates	Slit opening and guard cells; open into air spaces	Regulation of excretion Admit oxygen and CO ₂
Palisade cells	Oblong, endwise to surface Have chlorophyll grains	Expose chlorophyll to light
Chlorophyll	Green, living grains in the protoplasm	Make starch
Spongy cells	Irregular, loose Have chlorophyll grains	All leaf functions
Air spaces	Large and irregular Connect with stomates	Excretion Respiration
"Veins"	Duct bundles extending from the stem	Support Transportation

CHAPTER XIII

LEAF FUNCTIONS

Vocabulary

Illumination, source and supply of light.

Liberated, set free.

Photosynthesis, the process of starch formation in leaves, uniting carbon dioxide and water by means of light.

Soluble, that which can be dissolved.

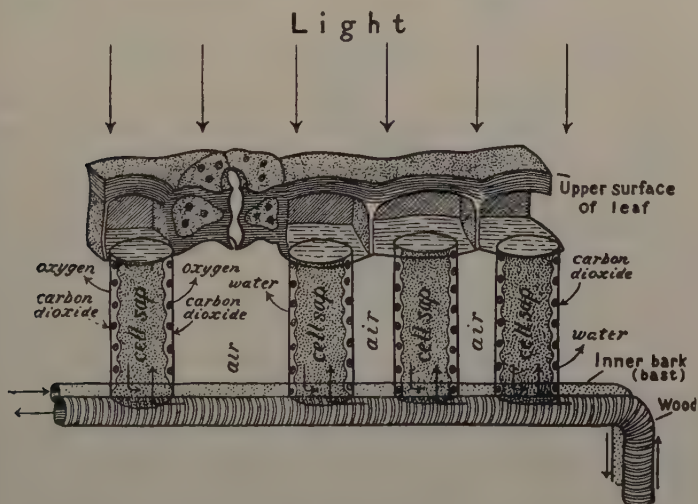
Photosynthesis. The process, by which carbon dioxide from the air and water from the soil are united by the leaves of plants to form starch through the action of sunlight on the green coloring matter in the leaves, is called photosynthesis (meaning combination by light).

The ability of plants to take these two non-living substances and build up their own food from them makes the chief distinction between plants and animals, for the latter depend on plant foods either directly or indirectly. They cannot use the raw materials as do the plants.

Chlorophyll. The essential feature of the leaf, so far as photosynthesis is concerned is the green coloring matter, chlorophyll (leaf green). This, as described in Chapter XII, is found in the palisade cells and spongy parenchyma, in the form of minute grains, embedded in the protoplasm.

Chlorophyll has the very wonderful property of absorbing some of the energy of the sun's light and by the utilization of this energy it is able to combine carbon dioxide and water into starch. This starch is the primary form of plant food. At the same time that starch is made, oxygen is thrown off as a waste product. This replaces in the atmosphere, that which is used in respiration by animals. Therefore animals depend on photosynthesis for both food and oxygen supply. It is evident now why so many adapta-

tions are found for exposing leaves to light, since, without light, starch-making cannot go on, and without starch the plant cannot survive. The chlorophyll is placed in the long palisade cells so that, if the light be weak, the chlorophyll bodies may move to the upper ends of the cells and get better illumination; or if the light is too bright, they line up along the sides and so escape the direct rays. In the deeper tissue of the spongy parenchyma of the leaf,



Courtesy of American Museum of Natural History

FIG. 25. Activities going on in the "cells" and air spaces of a leaf.

the chlorophyll is sufficiently protected and does not need to move in this way; here we find the cells irregular in shape.

Materials used in Photosynthesis. The water for starch making is supplied from the soil by means of the absorption of the roots. It rises to the leaves by way of the ducts and veins. Any excess is disposed of through the stomata. The carbon dioxide is supplied from the air, where oxidation, respiration, combustion, fermentation, and decay are constantly producing it. As fast as the plants remove it they return the oxygen. As a result the composition of the air remains practically constant.

The Energy for Photosynthesis. The chemical energy of the sun's light, which causes these two substances to unite, is something that we know very little about, but is, nevertheless, a very real and a very great force. We realize that the sun gives us light to see by, and heat is evident enough, but when we think of how it tans our skin, bleaches our clothes, and makes our photographs,

we have some evidences of the chemical action of light, though none of these can compare with the work done by these same rays in the leaf laboratory, during the making of starch in the plant.

This word photosynthesis can now be better understood, meaning as it does "union by means of light," since it is by the chemical power of the light rays that the water and carbon dioxide are united.

The leaf is sometimes compared to a mill in which the power is the sunlight; the machinery is the chlorophyll; the

raw materials are the carbon dioxide and water; the product is starch; and the waste material is oxygen.

The Waste Product. A benefit arising from photosynthesis almost as important as the production of starch itself, is the liberation of oxygen as a by-product. We have learned that every living tissue breathes *in* oxygen. The resulting oxidation produces the energy without which we could not live.

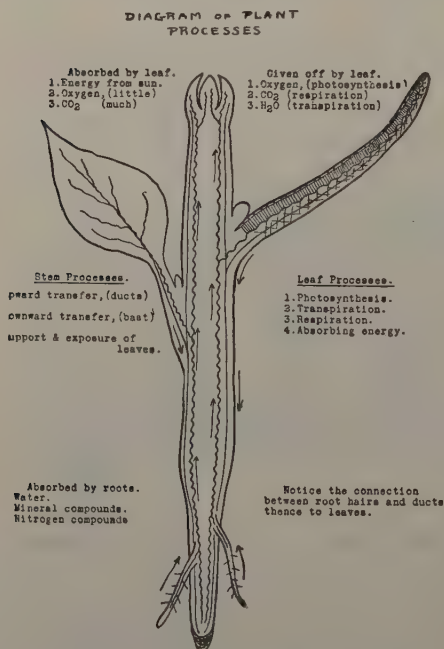


FIG. 26. Diagram of Plant Processes.

We have also learned that this oxidation produces carbon dioxide which we throw off in respiration. Now we can see that the plants use this discarded carbon dioxide for making *their* food, and return to *us* the oxygen which is necessary for our life.

This is a glimpse of one of the great "circles of nature."

Other Leaf Functions. Starch making, while the most important, is not the only function of leaves. In their marvelous chemical laboratory go on the processes of digestion, proteid manufacture, assimilation, respiration, and excretion of water (transpiration). *Digestion* is necessary to put the food stuff into soluble form so that it may act in osmosis and flow through the ducts. As to *proteid manufacture*, little is known, except that the carbon, hydrogen, and oxygen of the starch are combined with nitrogen, sulphur, and phosphorus from the soil water in a way that we cannot understand, much less imitate, and that proteids are the result of the process. *Assimilation* is active in leaves and all other living parts of the plant, since this is the process by which the nutrients actually become part of the living protoplasm and tissue of the organism. *Respiration* (oxidation) goes on wherever living plant tissue is directly exposed to air; while less active than in animals the process is just as essential, since it supplies the energy which keeps the plant alive. Much extra water is absorbed at times by the roots, in their transfer of nitrogen compounds and mineral salts from the soil. The useful elements are used in food making and the surplus water is passed off by way of the spongy layer, air spaces, and stomata. This process is called *transpiration* and differs from mere evaporation, in that the loss of water is regulated by the stomata and so corresponds to the needs of the plant. It does not depend upon the temperature alone, as does evaporation.

We find in the leaf the processes of food manufacture, digestion, and assimilation; these are building up, or constructive, processes and require a supply of energy from the sun or the living protoplasm to bring them about. This food is then united with oxygen, thereby releasing this sun-given energy. It is this energy which keeps the plant alive and permits it to grow. This last

process is, however, a destructive one as far as food and tissue are concerned and necessitates excretion in order to remove the waste.

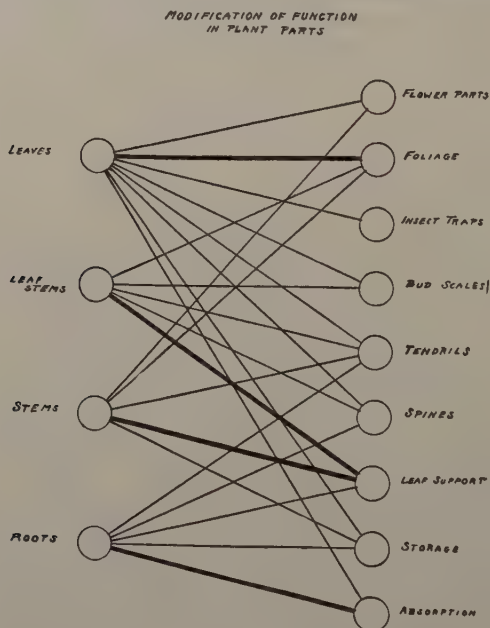


FIG. 27. Modification of Function in Plant Parts.

The circles at the left represent the usual parts of the plant, those at the right, the forms into which they may be modified, to perform the functions named.

The usual function is connected with its plant part by a heavy line; — those less frequent by lighter lines. Thus the roots' normal function is absorption, but it may be modified to form tendrils, spines, leaf supports, or for storage, as the lines show.

This diagram is intended to show the wide range of adaptation of structure to function.

SUMMARY

1. Photosynthesis.

The manufacture of starch from carbon dioxide and water.

2. Digestion.

Making the food soluble by means of plant enzymes, such as,

Diastase } acting on sugars and starches.
Maltase }

Lipase, acting on fats.

Pepto-trypsin acting on proteids.

3. Assimilation.

C, H, O, combined with N, S, P, etc., form proteids, etc.

4. Respiration.

Tissue and food plus oxygen = energy plus CO_2 .

5. Transpiration.

Giving off large excess of water.

The Leaf as a Factory

The factory	Green leaves (or other green tissue).
The work rooms	The cells of palisade and spongy layers.
The machines	Chlorophyll grains and protoplasm.
The power	Sunlight.
Materials	Carbon dioxide and soil water.
Supply department	Root hairs, ducts, air spaces, stomates.
Transportation dept.	Ducts, bast tubes, pith rays.
Finished products	Starch, sugar, proteids, tissues.
Waste product	Oxygen.
Hours of work	{ Manufacturing dept. daylight <i>only</i> .
	{ Transport and supply depts. day and night.

Comparison of Photosynthesis and Respiration*Photosynthesis*

Constructive process
 Food and tissue accumulated
 Energy taken in from sun
 Carbon dioxide taken in
 Oxygen given off
 Complex compounds formed
 Produces starch, etc.
 Goes on only by day
 Only in presence of chlorophyll

Respiration

Destructive process
 Food and tissue used up
 Energy released
 Carbon dioxide given off
 Oxygen taken in
 Simple compounds formed
 Produces CO_2 and H_2O
 Goes on day or night
 In all parts exposed to air

EXPERIMENTS WITH LEAVES

To show that Leaves (and Stems) turn toward Light. Two thrifty plants are provided, one is placed in a light-tight box,

with an opening at one side for light to enter. The other is placed under the same conditions of heat and moisture, but is given light from *all* sides.

The plant in the box will be found to turn toward the light and to grow rapidly in that direction. However, its stem will be weaker



FIG. 28.

Coleus leaf showing green and white areas, before treatment with iodine.

Similar leaf treated with iodine, the starch reaction only showing where the leaf was green. From Atkinson.

and slenderer, its leaves smaller and paler than the one with uniform lighting.

This experiment shows the response that plants make to light, and also the effect of a limited supply of light on their growth. Every time we see the leaves of house plants turning toward the window, we have a similar experiment in heliotropism. The plant kept outside the dark box was used as a check for this experiment.

Photosynthesis. To show that Green Plants produce Starch. Leaves can be taken from active green plants, scalded to kill the protoplasm and release the chlorophyll, and soaked in alcohol to remove the green color. Then, if tested with iodine, a dark blue color is produced, showing that starch was present. The chlorophyll had to be removed so that this blue could be seen. This proves that starch was in the leaf. To prove that it is *made there*, by the action of light on the chlorophyll, requires further experiment.

To show that chlorophyll is necessary, a leaf from a green and white-leaved geranium may be used, as above, when it will be found that little starch is revealed in the white portions.

To show that light is necessary, parts of an active leaf are covered with corks, pinned through, on both sides. After a few days the covered portions will not yield the starch test, while the exposed parts will still do so. Another proof of the same thing is to keep a plant entirely in the dark, as a check experiment, and when it has become pale, test for starch, which will be found lacking. Of course the same kind of plant, under the same conditions, except the light, should be used in this and in the experiment to be compared with it.

To show that Green Plants produce Oxygen. Oxygen is the waste product of photosynthesis; it is thrown off when starch is made. It is easier to collect a gas over water, hence a water plant is used for this experiment, but all green plants carry on the same process.

The water plant is submerged in a glass jar under a glass funnel, whose stem is covered by a small test tube, filled with water and inverted. The apparatus is set in the sun and soon bubbles of gas will rise in the funnel and be collected in the tube. These, when tested, prove to be oxygen. If carbon dioxide be dissolved in the water, the process will go on faster, as carbon dioxide is one of the materials used in photosynthesis, and that in the jar of water is soon exhausted.

Another similar experiment ought to be set up in the dark, so as to prove, again, that light is the source of energy for this very important process.

To prove that the oxygen did not come from the water, another check could be used, in which the apparatus was the same, but no plant was present, in which case no oxygen would be produced.

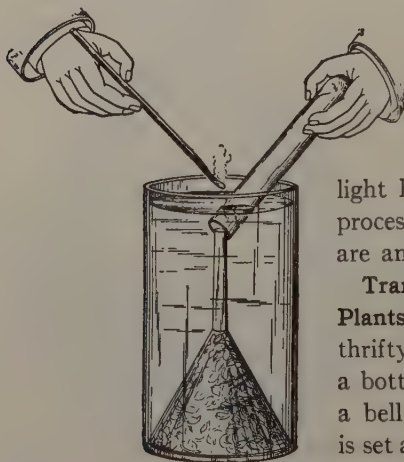
In experimental work of this kind, the check experiments show almost as much as the ones which actually "work." Merely stating that the water plant was put under the funnel, and that oxygen

was produced, would not prove anything. It would be asked "How do you know that the oxygen came from the plant?" and "How do you know that

light had anything to do with the process?" both of which questions are answered by the "checks."

Transpiration. To show that Plants pass off Water Vapor. A thrifty cutting is tightly sealed into a bottle of water and placed under a bell jar; another similar bell jar is set alongside, containing no plant. Water drops will soon be seen on the inside of the jar with the plant, none on the other. As the bottle

FIG. 29. Bubbles of gas will rise in the funnel. From Atkinson.



was sealed, no water could escape, except such as passed through the leaves of the plant. As the empty jar showed no water, it did not merely condense from the air, hence must have been passed off by the leaves. A potted plant could be used, but the pot and earth surface would have to be wrapped in oiled paper or sheet rubber, to prevent evaporation.

To show which surface of a leaf gives off this water vapor, two watch glasses can be fastened, one on either side of a leaf. More water will be found to condense on the glass fastened to the lower surface, showing that transpiration is more active here. This is as one would expect, since here the stomata are more numerous.

Cobalt paper, which turns pink when moist, can also be fastened

to the upper and lower surfaces of a leaf, and will show the same result.

Thus the end products of all these processes are the carbon dioxide and water, with which the photosynthesis started. The oxygen involved in the destructive processes is the by-product of photosynthesis, so that all three elements, carbon, hydrogen, and oxygen pursue a circular course.



FIG. 30.



FIG. 31.



Figure 30 shows plant with pot sealed, but giving off water vapor which has condensed on bell jar.

Figure 31. Left-hand figure, shows plant with sealed pot, giving off water vapor enough to turn the cobalt paper pink within fifteen minutes. The right-hand figure is a check experiment, to show that the moisture in the air would not cause the change in the same time. From Atkinson.

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Plant Relations, Coulter, pp. 148-161; *Botany for Schools*, Atkinson, pp. 90-116; *Elementary Botany*, Atkinson, pp. 53-70; *First Studies in Plant Life*, Atkinson, pp. 121-125; *Lessons in Botany*, Atkinson, pp. 70-72; *Experiments in Plants*, Osterhout, pp. 191-202; *Biology Text*, Hunter, pp. 132-134; *Essentials of Biology*, Hunter, pp. 115-132; *Introduction to Biology*, Bigelow, pp. 55-75; *Plant Life and its Uses*, Coulter, pp. 218-234; *The Great World's Farm*, Gaye, pp. 157-176; *The Story of the Plants*, Allen, pp. 33-53; *Textbook of Botany*, Gray, pp. 85-110.

PRODUCTS OF PHOTOSYNTHESIS

$\left. \begin{array}{l} \text{CO}_2 \\ \text{and} \\ \text{H}_2\text{O} \end{array} \right\} \text{form} \left\{ \begin{array}{l} \text{Starch} \\ \text{and} \\ \text{Sugar} \end{array} \right\} \text{used for}$	$\left\{ \begin{array}{l} \text{Foods, 50 \%} \\ \text{Support, 25 \%} \end{array} \right\} \left\{ \begin{array}{l} \text{Plant growth, 25 \%} \\ \text{Eaten by animals, 25 \%} \\ \text{burns or decays to produce} \end{array} \right\}$	$\left\{ \begin{array}{l} \text{respiration or decay} \\ \text{produces} \\ \text{CO}_2 \text{ and H}_2\text{O} \end{array} \right\}$	$\left\{ \begin{array}{l} \text{CO}_2 \text{ and H}_2\text{O} \\ \text{CO}_2 \text{ and H}_2\text{O} \\ \text{CO}_2 \text{ and H}_2\text{O} \end{array} \right\}$
$\left\{ \begin{array}{l} \text{CO}_2 \\ \text{and} \\ \text{H}_2\text{O} \end{array} \right\} \text{form} \left\{ \begin{array}{l} \text{Starch} \\ \text{and} \\ \text{Sugar} \end{array} \right\} \text{used for}$	$\left\{ \begin{array}{l} \text{Protoplasm, 10 \%} \\ \text{Oxidation, 15 \%} \end{array} \right\}$	$\left\{ \begin{array}{l} \text{decays to produce} \\ \text{respiration produces} \end{array} \right\}$	$\left\{ \begin{array}{l} \text{CO}_2 \text{ and H}_2\text{O} \\ \text{CO}_2 \text{ and H}_2\text{O} \end{array} \right\}$

The Living Plant. Adapted from Ganong

Process	Where done	Apparatus	Materials	Energy from	Products	Waste
Starch making or photosynthesis	Palisade and spongy cells of leaf, green bark of stem	Chlorophyll and proto- plasm	$5\text{H}_2\text{O} + 6\text{CO}_2 =$ $\text{C}_6\text{H}_{10}\text{O}_5 + \text{O}_2$	Sun, 1 horse power per five square feet	Starch, $\frac{2}{3}$ oz. per square yard	Oxygen
Digestion	All living parts	Ferments	Starches and proteids rendered soluble	Vitality of plant, process goes on regardless of light	Soluble food stuffs	
Assimilation	All living parts, especially roots, trunk, and branches		Digested starch, ni- trates — S. P. taken from soil	Vitality of plant, <i>i.e.</i> protoplasm which gets en- ergy by oxida- tion of C, dark- ness or light	Protoplasm, tissue, stored proteids, cel- lulose, lignin, suberin, etc.	
Respiration	All exposed parts	Stomates and lenticels	O from air, C and H from plant	Chemical affinity of O for H and C, goes on con- stantly	Energy of plant, little heat	CO_2 , little, no- ticeable only at night
Transpiration	Spongy paren- chyma to air spaces	Stomates reg- ulated by way of pro- toplasm	Soil water (sap)	Heat, evapora- tion, root pres- sure must keep up	Water for starch, NO_3 , S, P from proteids, mineralsubs. in stems	Water, much: stored salts

CHAPTER XIV

FLOWERS: POLLENATION AND FERTILIZATION

Vocabulary

Pollenation, transference of pollen from anther to stigma.

Fertilization, union of sperm nucleus and ovule nucleus to form the embryo.

Conspicuous, noticeable.

Glands, organs for secretion of any liquid, as nectar glands.

Nectar, a sweet liquid secreted by plants to attract insects. Bees make it into honey; plants do not secrete *honey*.

Learn names of flower parts from the text.

If we refer to the list of life functions it will be seen that we have dealt with all of them except reproduction. All the others have had to do with the life of one individual plant, its food getting, energy production, or waste removal. Now we have to do with a function as important as all the rest, the propagation of new individuals.

The Function of the Flower. In most of the common plants the flower is the organ whose function is reproduction, and, while there are other methods, we shall deal with the commonest one first, since it is found in at least 130,000 different kinds of plants.

The final product of the flower is the seed. To produce the seed, fertilization must take place and to cause fertilization, pollenation must precede it. While these terms will be made plain later, we can remember that the flower is provided with means for securing pollenation, fertilization, and seed production.

Structure of the Flower. We will take for an example the geranium, either a "single" flowered house species or the common wild geranium, which though different as to genus, is still sufficiently similar for our purpose. As we look at the flower from the rear, or stem side, we will see a row of small green, leaf-like

organs called the *sepals*. This is the *calyx*. Its function is to protect the flower in the bud condition and to help support the other parts when it opens.

Inside the calyx comes the *corolla* consisting of a row of colored parts called *petals*. These are often for the attraction of insects as we shall see when studying pollination, and may also help to protect the inner and more essential parts.

Next inside the corolla we will come to several knobbed, hair-like organs. These are the *stamens*. The knobs at their tops (anthers) are very important, as they produce and scatter a yellow, dust-like substance known as *pollen*. They are placed on these thread-like supports (filaments) so that the pollen will have a better chance to be distributed.

In the very center of the flower is the *pistil* consisting of a sticky knob at the top (stigma) to catch pollen, a slender stalk (style) to support the stigma, and an enlarged portion at the base (ovary) which contains the undeveloped seeds (ovules) and later develops into the fruit.

Pollination. In order that a flower may produce seed, the pollen must be transferred from the anther to the stigma, and usually it must be from the anther of one flower to the stigma of another of the same kind. This transfer of pollen from anther to stigma is called *pollination*. If, as in most cases, it is between different flowers, it is called *cross pollination* and is the process for which the flower parts are adapted. Insects and wind are the two chief

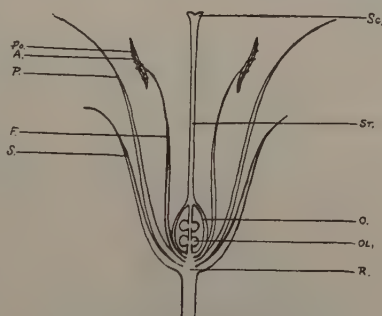


DIAGRAM OF TYPICAL FLOWER

R. RECEPTACLE.	
S. SEPAL, (CALYX)	
P. PETAL, (COROLLA)	
	<u>STAMEN</u>
	A. ANTHER
	F. FILAMENT
	<u>PISTIL</u>
	St. STIGMA
	St. STYLE
	O. OVARY
	Ol. OVULES

FIG. 32. The flower is provided with means for seed production.

agents in pollination and there is no process for which more curious adaptations have been developed. We shall deal first with those that fit the flower for pollination by insects.

Adaptations for Insect Pollination. The bee and the flower are associated in our minds, of course, but it is not so commonly realized that one could not exist without the other, and that many other insects, besides bees, are just as closely concerned.

The insect comes to get its food from the sugary *nectar* which is secreted at the base of the petals; in getting this, its body catches some of the pollen from the stamens which are shaped for this purpose. When the insect visits the next flower some pollen is sure to be rubbed off on the pistil of that flower, and a new supply

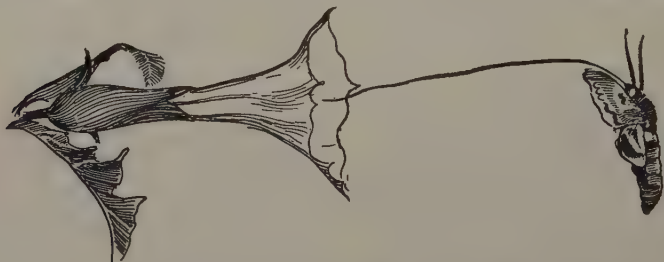


FIG. 33. Hawk-moth posed before a jimson-weed, *Datura stramonium* (after Stevens; one-half natural size).

brushed from the stamens as it crawls out. In this way pollination is accomplished.

In order that the insects may surely see each flower, they have developed conspicuously colored corolla and attractive odors. They often grow in clusters so as to be easily noticed and visited. After the insect arrives, not only does it find a reward of nectar, but often the flower is shaped to provide a convenient landing place. Colored lines lead to the nectar glands. Stamens and pistils hold their anthers and stigmas in just the proper position so that pollen shall be transferred while the insect is obtaining its sweet reward for unintended labors.

Nearly every flower has a slightly different scheme for cross pollination. When we find one with irregular-shaped corolla, we

may be almost sure that some special adaptation for insect visitors stands behind the curious shape.

Adaptations for Wind Pollenation. Flowers which depend on wind for their pollination are very differently adapted. They produce enormous quantities of pollen, but they have no nectar or odor. Their pistil is usually large to catch the flying pollen, and they secure access to the wind by having very small corollas and by producing their flowers above the leaves of the plant.

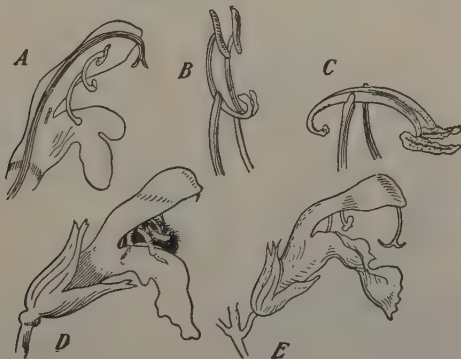


FIG. 34. *Salvia*-flower.

- A, showing position of pistil and stamens;
- B, anthers of stamens in normal position;
- C, anthers of stamens tipped down;
- D, bee entering flower;
- E, flower, natural condition.

(After Lubbock, natural size.)

Many grasses and sedges and all the evergreen trees have their pollen distributed by the wind. In fact, near large pine forests the yellow pollen fills the air and covers the ground at certain seasons, forming what people call "sulphur showers."

Protection of Pollen. Since pollen is absolutely necessary to the plant, it has to be protected from rain and from insects which would eat it and from those which are too small or too smooth-bodied to carry it. Protection against rain and dew is secured by the drooping or closing of the corolla, while unwelcome insect

visitors are kept out by hairy or sticky coatings on stem and calyx or on the inside of the corolla.

Essential Organs. Notice that the only organs absolutely needed



FIG. 35. *Spartium*, showing the dusting of the pollen through the opening keels on the under side of an insect. (From Kerner and Oliver, see Kellogg.)

to produce seeds are the stamens and pistil. Hence they are called the "essential organs." The corolla and calyx have; as their function, the protection of these essential organs and the securing of pollination.

The pollen grain from the anther and the ovule in the ovary are actually the most necessary factors in the process of reproduction and must now be dealt with more completely.

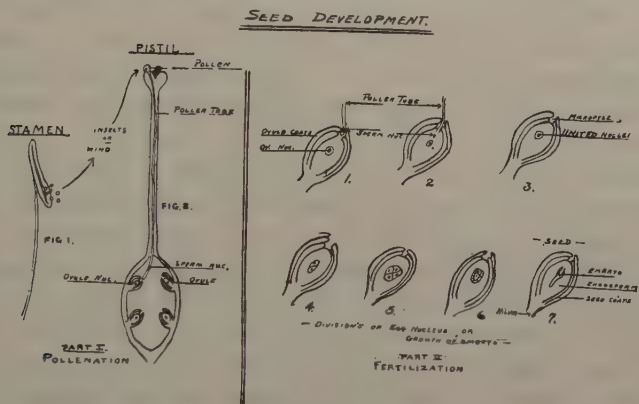


FIG. 36. Seed Development.

Part I. Pollination

Fig. 1. The stamen is shown with part of the filament, and the anther opening to set free the pollen. This may be transported either by wind or insects, to the stigma of the pistil of a similar kind of flower, shown in Fig. 2.

After arriving there, the pollen develops a long tubular cell which reaches clear to the ovary, down the whole length of the style, even though it be as long as a "silk" of corn.

The development of this tube, and the passage of the sperm nucleus from the pollen, down it, are shown here, though they are really steps in fertilization. Pollination is really the mere transfer of the pollen.

Part II. Fertilization.

Fig. 1. The pollen tube is entering the micropyle and the sperm nucleus is at its lower end. Note the ovule nucleus, with which it is to unite. Both one-celled stages.

Fig. 2. The sperm nucleus has passed out of the pollen tube and is approaching the ovule nucleus.

Fig. 3. The sperm and ovule nuclei have united; — this is the actual fertilization, from which the development of the embryo begins.

Fig. 4, 5 and 6 show stages in the early cell divisions as the embryo develops.

Fig. 7 shows the matured seed. The parts of the embryo have gone as far as they will till germination commences. Extra stored food remains unused outside, as endosperm.

Pollen Structure. The pollen grain is at first a single cell but if transferred to the stigma of a flower of its own kind, it begins to grow, forming three cells, one of which develops into a very long tube which reaches from stigma to ovary, no matter how long that may be. The other two cells, containing the most active kind of protoplasm, are called the *sperm* or male cells, and their union with the ovule is called fertilization and produces the embryo in the seed.

Ovule Structure. The ovules (undeveloped seeds) are protected inside the ovary and can be reached only by way of the pollen tube from pollen grains on the stigma. They are much larger and more complicated than the pollen grains. Each ovule in the ovary has a protective covering which later becomes the testa of the seed. Within this is the nucleus of the ovule cell which divides into eight cells, two of which form the endosperm and one, the most important, becomes the egg or female cell. As has been said, the pollen tube grows downward through the style till it reaches the place where an ovule is attached to the ovary wall; near this point of attachment is an opening through the ovule coats, called the micropyle, and through this the pollen tube makes its way till it reaches the egg cell within.

Fertilization. The sperm cell then passes down the pollen tube and unites with the protoplasm of the egg nucleus. This union of the sperm nucleus of the pollen with the egg nucleus of the ovule is called fertilization. The fertilized egg now has the very remarkable power to grow, and from its one cell, to develop the countless numbers which go to make up the embryo within the seed and finally the whole new plant. Notice that in this wonderful process each plant is reduced to a single cell, the sperm or the egg, — that they unite and again form a single cell, and that from this develop the embryo and the whole organism.

Fertilization is essentially the same in both plant and animal so you must try to think of all living things as having developed from a single fertilized egg cell.

Origin of Seed Parts. Look back at Chapter VI and notice that we have just been studying the origin of all parts mentioned

in the structure of the seed: the ovule walls become the testa and tegumen; the opening for the pollen tube is the micropyle; the fertilized egg develops into the embryo, and the endosperm nuclei produce the endosperm.

The embryo may develop to a great extent within the seed and use all the endosperm, or it may develop but little and leave unused endosperm for the germination process. In either case it was present at one time.

Notice that the seed stage is only a pause in the continuous circle of growth. The parent plants produce the pollen and ovules; these produce sperm and egg; both grow and finally unite. The embryo is formed and grows more or less within the seed, then merely waits and rests till it shall have conditions favorable for continuing its growth to an adult plant, again. In this way the life cycle is completed. The parents die but parts of their actual protoplasm live on, forever, in the new generation.

COLLATERAL READING

POLLENATION

Cross and Self Fertilization in the Vegetable Kingdom, Darwin; *The Great World's Farm*, Gaye, pp. 208-214; *With the Wild Flowers*, Hardinge, pp. 47-55; *Ten New England Blossoms*, Weed, pp. 1-17, 90-98; *Beauties of Nature*, Lubbock, pp. 117-138; *The Fairy Land of Science*, Buckley, p. 212-237; *Elementary Studies in Botany*, Coulter, pp. 151-166; *Plant Life and Uses*, Coulter, pp. 301-322; *Natural History of Plants*, Kerner and Oliver, Vol. II, Part 1, pp. 129-283, 426-436, Part 2, 833-840, 862-866; *Experiments in Plants*, Osterhout, pp. 286-311; *Plants and their Children*, Dana, pp. 187-255; *The Living Plant*, Ganong, pp. 303-326; *Practical Biology*, Smallwood, pp. 296-308; *The Story of Plants*, Allen, pp. 73-135; *Outline of Botany*, Leavitt, pp. 120-127; *Textbook of Botany*, Bessey, p. 421; *Textbook of Botany*, Strasburger, pp. 281-283; *Plant Relations*, Coulter, pp. 123-137; *Introduction to Botany*, Stevens, pp. 166-201; *Plant Structures*, Coulter, p. 181; *Nature and Work of Plants*, McDougal, pp. 149-153; *Lessons in Botany*, Atkinson, pp. 192-193; *Elementary Botany*, Atkinson, pp. 351-367; *Botany for Schools*, Atkinson, pp. 167-181; *Elementary Biology*, Peabody and Hunt, pp. 74-88; *Flowers, Fruits and Leaves*, Lubbock, pp. 1-44; *Plant Life*, Step, pp. 35-58; *Wonders of Plant Life*, Herrick, pp. 149-173; *Blossom Hosts and Insect Guests*, Gibson, entire; *Flowers and their Friends*, pp. 121-133; 231-239; *Fertilization in the Vegetable Kingdom*, Darwin, pp. 356-414.

FERTILIZATION

Botany for Schools, Atkinson, pp. 182-186; *Elementary Biology*, Peabody and Hunt, pp. 74-88.

FLOWER STRUCTURE

Plant Structures, Coulter, pp. 218-231; *Lessons with Plants*, Bailey, pp. 131-150; *Botany for Schools*, Atkinson, pp. 140-166; *Elementary Biology*, Peabody and Hunt, pp. 70-74; *Plant Life and Uses*, Coulter, pp. 258-300; *Applied Biology*, Bigelow, pp. 196-213.

SUMMARY

Function of flower, reproduction by means of seeds.

Steps in seed production.

1. Pollenation.
2. Fertilization.
3. Growth of embryo in seed.

Flower parts.

Calyx (sepals)
Corolla (petals)

Stamens,
 Anther
 Filament

Pistil,
 Stigma

Style

Ovary

Function.

Protection and support.
Insect attraction for pollenation.
Protection of essential organs.

Production of pollen.
Support of anther for pollenation.

To catch pollen: sticky, sometimes large.

To support stigma so as to catch pollen.

Contains ovules, forms fruit.

Pollenation.

Definition. Meaning of "cross-pollenation."

Means for pollenation:

Insects (clover, etc.)

Adaptations for insect pollenation.

Nectar,	Odor,
Bright color,	Growth in clusters,
Landing places,	Special shapes.

Wind (pine, corn, grasses, etc.)

Adaptations for wind pollenation.

Flowers high above leaves, not conspicuous.

Petals and sepals small or lacking.

Pistils large and sticky.

Abundant pollen (why?)

No nectar nor odor.

Pollen protection.

From rain by closing or drooping of flower.

From unwelcome insects by sticky stems or hairy flowers.

Essential organs.

What are they?

Why so called?

Fertilization.

Definition: union of sperm nucleus of pollen with egg nucleus of the ovule.

Pollen.

1. Produced by stamen (anther).
2. Structure: one-cell stage.
Three cell stage.
Pollen tube (use ?).
Sperm cells (use ?).

Ovule.

1. Produced in the ovary: undeveloped seed.
2. Structure: coverings (seed coats later).
One-cell stage.
Eight-cell stage.
Two cells from endosperm.
One forms egg cell, proper.

Fertilization.

1. Pollen tube penetrates micropyle.
2. Sperm cell passes down pollen tube.
3. Nuclei of sperm and egg unite (fertilization proper).
4. Embryo begins to develop.

Origin of seed parts.

1. Ovule walls become seed coats.
2. Opening for pollen tube is the micropyle.
3. Fertilized egg becomes the embryo.
4. Endosperm nuclei become the endosperm.
Endosperm may be used by developing embryo.
Endosperm may remain to be used in germination.

CHAPTER XV

FRUITS AND THEIR USES

Vocabulary

Matured, fully developed.

Infinite, endless.

Superficial, careless.

Relatively, comparatively.

While the seeds are developing, the ovary grows also, and the final result is what we call a fruit. This does not necessarily mean "fruit" in the sense of a fleshy edible product, but applies to the seed-holding organ of any plant. A fruit may be defined as the matured ovary, its contents, and all intimately connected parts. Thus a fruit may consist of a single ovary with only one seed, as in grains, nuts, cherries, or plums, or it may develop from a single ovary which has several seeds, as in pansy, pea, poppy, or apple. On the other hand there are many flowers which have several ovaries. These combine to form compound fruits like the strawberry or raspberry. Fruits may therefore be either dry or fleshy, simple or compound, depending on the character and development of the ovary which formed them.

Types of Fruits. The peach is a good example of a one-celled, simple, fleshy fruit. In it the ovary wall develops two parts, an outer fleshy layer and the hard inner "stone" which encloses the seed. Such a fruit is called a *stone fruit*.

The apple develops from a five-celled ovary which forms the core. Outside of this is a fleshy region, usually bounded by a faint line which is probably the fleshy ovary wall, or may be an enlarged receptacle. Outside of this is the bulk of the apple, which is a greatly thickened calyx, as is indicated by the five tiny sepal tips which persist at the blossom end. Inside these tips the dried sta-

mens and pistil may sometimes be found. A section through an apple shows the outer skin, the calyx layer, the fleshy ovary wall, the hard ovary wall and the seeds attached to the central axis, with their points toward the stem. A fruit of this type is called a *pome* and is represented by the apple, pear, quince, and medlar.

The bean pod is a type of a many-seeded dry fruit, called a *legume*. At the stem end may be found the remains of the calyx lobes. The bulk of the pod is the ovary; the pointed tip is the style, on which the stigma may sometimes be found in young pods, as a tiny knob. The "string" is a vascular bundle bringing nourishment to the growing ovules, which are attached along one side of the pod. Their point of attachment is called the placenta, and the scar left on the seed, when it is removed, is the hilum. The bean fruit thus includes mainly the greatly enlarged ovary and its contents, with the style and possibly the stigma also.

Functions of Fruits. The chief functions of fruits are to protect the ovules and seeds from attack by insects, or fungous spores; to prevent loss of water; and to provide for dispersal. To provide for these purposes the ovary develops in various ways. Tufts of hair, wings, or hooks may be produced to aid in dispersal. Tough shells or rinds may form for protection as in nuts or lemons. Delicious flesh may envelop the hard inner stone, tempting animals to eat the fruit and discard the seed at a distance from the parent tree. The peach or cherry are examples of this. In addition to the developments of the ovary wall, the calyx may become fleshy and envelop the ovary as in apples and pears. In other cases the end of the stem (receptacle) enlarges and becomes a part of the fruit, as in the case of the strawberry and blackberry.

Seed Dispersal. That the ovary wall protects the seeds from insect attack, drought, decay, and weather is plain enough, but how the other function, dispersal, is accomplished may not be so evident. The most superficial observation of any common plant, such as the dandelion, will reveal two facts: (1) an enormous number of seeds are produced and (2) each full-grown plant requires a

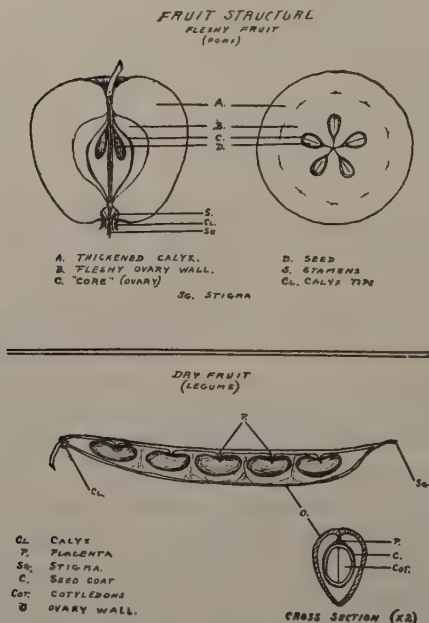


FIG. 37. Fruit Structure.

Figs. 1 and 2. The Apple. — These drawings are diagrammatic, but intend to show the origin and structure of the regions in one of the more complicated fleshy fruits.

The outer region, (A) is probably the greatly thickened calyx, as the persistence of the five calyx tips at the blossom end would indicate. However some botanists consider it to be an enlarged end of the stem called the receptacle, which has carried up the calyx lobes with its growth.

The region (B) shows in most apples by being separated from (A) by a faint line or row of dots. This is the fleshy outer wall of the ovary. Inside of this region is where "water cores" sometimes develop.

(C) is the real "core" of the apple, tough and leathery enclosing the seeds (D). This core has five chambers or cells enclosing one or more seeds. Running through the center is a tough axis to which the seeds are attached, with their points toward the stem end.

These same parts are shown in the cross section, and the seeds are cut in two which shows the two cotyledons in each.

In the cavity at the blossom end may sometimes be found the dried up remains of the stigma and stamens.

The parts included in the apple are the calyx and ovary at least, and possibly others.

Figs. 3 and 4. The Bean. — This is a typical dry fruit with several seeds, which opens to scatter them.

It consists of the fully developed pistil, the bulk being the greatly enlarged ovary, with the stigma reduced to the tapering tip, and the stigma usually fallen off in a fully matured pod.

The "string" which we remove in preparing for food, is a duct bundle that brought nourishment to the ovules and reached each by way of the hilum.

The point of attachment to the pod is the placenta, (P) and shows in both drawings.

The pod is the thickened ovary wall (O), and at its base the shriveled calyx is sometimes found.

The cross section shows a seed cut across, displaying the seed coats (C), and the two cotyledons (Cot.).

relatively large amount of room. Evidently, then, the seeds must be scattered if they are to survive, and usually those plants producing most seeds or needing most room best attend to this matter of seed dispersal. There is scarcely a more interesting chapter in biology than this one which deals with the wonderful adaptations by which seeds, though having no power of locomotion, still manage to transport themselves long distances and in great numbers. Plants use the wind, water, animals, and various mechanical schemes to scatter their seeds. Sometimes it is the seed by itself which is transported, sometimes the whole fruit, but the end is the same, to get a new place where there shall be space, food, light, and moisture for the development of the waiting embryo.

Adaptation for Wind Dispersal. Adaptations for wind dispersal are found in the tufts of down on thistle and dandelion fruits and milkweed seed, in the wings on the fruits of elm, ash, or maple, or on the seeds of the catalpa or pine.

Adaptations for Dispersal by Animals. Burs and hooks, as in burdock and "pitchforks," enable the fruits to steal rides on animals and man, and get themselves picked or shaken off at great distances. The delicious flesh of peach or apple, grape or berry is merely a sort of bribe to reward some animal for carrying off the fruit. The seeds of all such are indigestible and so are carried far from the parent plant. It is noteworthy that unripe fruits are usually poisonous or bad tasting. Thus they are not eaten before the seed is ready for dispersal.

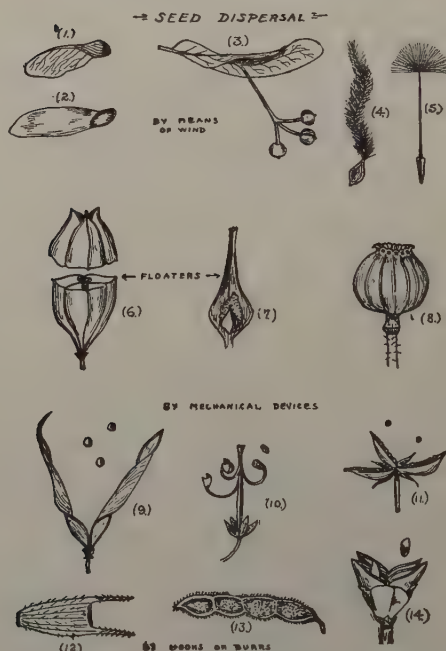


FIG. 38. Seed dispersal.

No. 1. Maple "key," one of a pair of fruits which separate as they fall. They whirl in a horizontal plane, and so fall slowly and are blown to some distance. The heavy end works down to the ground, giving the enclosed seed a chance to germinate.

No. 2. Pine seed. Not a fruit, like the maple, though dispersed in the same way. Shaken out of the cone when ripe.

No. 3. The Bass-wood. A group of fruits, with a parachute which lets them fall slowly and so reach some distance, also it will drag them some farther after alighting, especially on a "crust" in the winter.

No. 4, Clematis and No. 5, the Dandelion, are both fruits with parachutes made of downy hairs. The Milkweed has a similar device on its seed.

No. 6, the Bladder-nut and No. 7, a Sedge, are both provided with water-tight life preservers, which float the seeds to distant landing places. Bladder-nut is also light enough to blow.

No. 8. The Poppy fruit, has many tiny openings at the top of its "pepper box" capsule. The stem is stiff and springy and the small heavy seeds whip out in the wind, a few at a time, assuring at least some of them, favorable conditions.

No. 9. The Pea, a type of all the family, which throws out the seeds by the twisting of the pod, as it dries.

No. 10. The Wild Geranium, slings its seeds, as the pod splits upward.

No. 11, the Violet and No. 14, the Witch-hazel, pinch their seeds out, as the pod dries and closes together.

No. 12, the "Pitch-fork" and No. 13, Desmodium, catch on animals, by their hooks, and are thus scattered.

Dispersal by Water. A considerable number of plants secure dispersal by having fruits that float, without absorbing water,



FIG. 39. Milkweed (*Asclepias cornitu*) dissemination of seed. From Atkinson.

and so are carried by rivers or ocean currents to favorable places along the shore. Sedges and coconuts are examples of this type.

Mechanical Dispersal. Some of the most curious adaptations for seed dispersal are the mechanical devices by which seeds are thrown from the pods for a considerable distance. The touch-me-not,

whose pod explodes when ripe; the witch hazel, which pinches the seed between the open ovary walls till it shoots out; the tall stalked mullein and poppy, which whip in the wind and sling their fine heavy seeds far away are examples of this interesting type.



FIG. 40. Seed distribution of Virgin's Bower (clematis). From Atkinson.

Economic Importance of Fruits. So far as the plant is concerned, the object of the fruit is to secure reproduction by providing the enclosed seeds with protection and transportation. However, man has learned to depend upon fruits for food and other uses, so

that they are the most important part of the plant for his purposes.

To begin with, we must remember that the grains, such as wheat, rice, and corn, are *fruits* and not merely seeds as we commonly think. These furnish more food than all other plant parts, combined. Then there are the fleshy fruits — like the apple, orange, grape, and peach — which we use raw, cooked, and canned, and from which many other food products are manufactured. From the downy contents of the cotton boll we obtain that most essential fiber, which nature intended to help in dispersing the seed.

On the other hand, the fruits of some weeds are altogether too efficient in their methods of dispersal, and we have to fight the spread of plants like the dandelion, hawk weed, burdock, and thistle. Some fruits are poisonous, presumably better to protect the seeds, and these occasionally do harm to man; among them may be mentioned the Jimson weed, night-shade, and water hemlock.

COLLATERAL READING

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SUMMARY

1. Definition of Fruit
2. Types of fruits.
 - Stone fruit, one-celled, fleshy (peach).
 - Pome, many-celled, fleshy (apple).
 - Grain or nut, one-celled, dry (corn, pecan)
 - Legume, many-celled, dry (bean).
3. Functions of fruits.
 - Protection.
 - Dispersal.

4. Dispersal.

Reason for dispersal.

Means of dispersal:

1. Wind, adaptations for wind dispersal.
Tufts of down (dandelion, thistle).
Wings (maple, ash, elm).
2. Animals, adaptations for animal dispersal.
Burs (burdock).
Hooks ("pitchforks").
Edible flesh (peach).
Hard or bitter "pits" (why?)
Bad tasting when unripe (why?)
3. Water.
4. Mechanical devices.
Explosive fruits (touch-me-not).
Pinching fruits (witch hazel).
Whipping fruits (poppy, mullein).

5. Economic Importance.

Plant propagation.

Food supply (cereals and fleshy fruits).

Cotton fiber.

Harmful weed seeds.

Poisonous fruits.

CHAPTER XVI

SPORE-BEARING PLANTS

Vocabulary

Complicated, not simple in structure.

Parasite, plant or animal which obtains nourishment at the expense of another.

Scavengers, destroyers of waste matter.

The majority of plants with which we are familiar obtain food, grow and reproduce by root, leaf, flower, and fruit, just as we have been learning, but there are a large number of important, but less conspicuous, forms that have no flowers, and so produce no seeds. These flowerless plants reproduce by single cells called *spores* which, by a more or less complicated process, develop into the plant again.

Classification of Spore Plants. The simplest of these flowerless plants are the *algae*, which may consist of only one cell as in *pleurococcus* which forms the green coating often seen on stones, bark, and old fences, or they may grow to large, many celled forms, such as the sea weeds, or from the green mats of pond scum (*Spirogyra*) that cover our ponds. The *fungi* are another large group of spore plants which have no chlorophyll and hence have to depend on other plants or animals for organic food. They are parasites, and among them we find mushrooms, puff balls, moulds, yeast, and bacteria. The next group, *lichens*, are really organisms consisting of algae and fungi living together as one plant and are familiar as the variously colored, flat, scaly forms that grow in patches on rocks and trees. More familiar still are the *mosses* forming the green carpet of the woods, and finally we come to the largest and most complicated of the spore plants, the *ferns* and their relatives, the horse-tails and ground-pines.

While it is not necessary to learn these names or figures, the following table will show you how large and varied the plant kingdom really is and how few we know of its members.



FIG. 41. Rock lichen (*Parmelia contigua*). From Atkinson.

Flowering plants, spermatophytes (producing seeds):		
True flowering plants and	}	130,000 kinds
Pines and their relatives		
Flowerless plants (producing spores)		96,600 kinds
Thallophytes (algae and fungi):		
Algae		16,000 kinds
Fungi		55,000 kinds
Bryophytes (mosses and their relatives)		16,500 kinds
Lichens		5,600 kinds
Ferns		3,500 kinds

The Fungi. With the exception of the fungi, all these plants have chlorophyll and so can make their own starch foods; but this particular group has developed the habit of taking its food from other plants or animals, either dead or alive, and so are called parasites. This parasitic habit crops out occasionally in the flowering plants, also, such as the Indian pipe and beech drops but they, as well as all the fungi, pay a twofold penalty for their laziness.

Results of Parasitic Habit. When a plant or animal ceases to use an organ that organ degenerates, and the plant or animal loses the ability to use it. So it is with the fungi; they can no longer make their own organic food, and are totally dependent on others for their life. They have to produce millions of spores, since only a few can hope to survive.

Many fungi perform a useful function in nature by using dead organic tissue for their food, thus acting as scavengers. They also convert such useless matter into food materials which the higher plants can use again. Fungi that feed on dead organic tissue may be useful as scavengers, but unfortunately this dead tissue may also be needed by man for food. The fungi that attack our stored meats and vegetables cause a great deal of loss and expense.

Because of this habit, the fungi bear a peculiar and important relation to other plants and animals, and especially to man. Therefore we shall deal with them as an example of the spore-producing type of plants.

Examples of Fungi. *The mushrooms* are the largest fungous forms and while some few are edible the majority are useless for food. Many are poisonous, and the shelf-shaped mushrooms found on trees do enormous damage to timber. Just a word of warning at this point: a "toad stool" is merely a name that some people attach to poisonous mushrooms. There is really no such difference. No "rule" or "sign" can be given by which you may distinguish poisonous forms. Their food value is very slight while the poison of the harmful forms is usually fatal. Bearing this in mind there is but one conclusion, either learn to recognize one or

two edible kinds and use them *only*, or leave them all severely alone as food.

Another class of the fungi includes the *rusts* and *smuts* which attack grains, corn, and other grasses, doing enormous damage to crops. *Mildew* is a common fungus whose chief harm is the causing of rot in potato and similar crops, and destruction of grapes and other fruits. *Molds* are also familiar forms which thrive upon

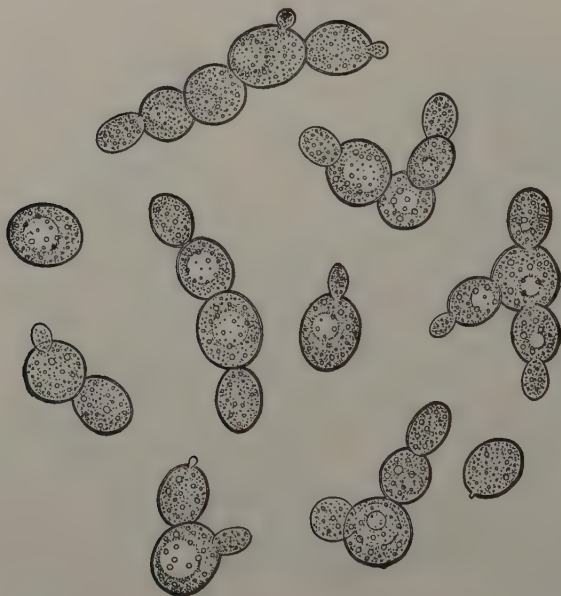


FIG. 42. Colonies of budding yeast cells (Sedgewick and Wilson)
From Calkins.

food stuffs, bread, meats, canned fruits, and even wood and paper, if conditions are such that their spores can germinate.

Yeast plants are a still simpler class of fungi. We use them so commonly that we hardly realize that they are plants at all. Yeast, however, is a true one-celled plant, living on dilute sugar solutions which it changes to alcohol. It sets free carbon dioxide gas as a waste product. Thus yeast is used in two very different kinds of

industry, the manufacture of alcoholic liquors, where the alcohol is the desired product, and in the making of bread, where the carbon dioxide is required to make the loaf "light" by its expansion. Yeast consists of single oval cells. It reproduces very rapidly if kept warm and moist and supplied with sugar for food. Buds develop on each parent cell and soon become full-sized cells which again reproduce, the process being extremely rapid. A loaf of bread is the product of at least two very different kinds of plants, (1) the complicated wheat plant whose store of starch we make into flour and (2) the simple yeast which helps to make it palatable.

We have left till the last the most important member of the fungous group — the *bacteria*. They are of such vast influence both for good and harm, that the next chapter will be entirely devoted to them.

COLLATERAL READING

Applied Biology, Bigelow, pp. 232–297; *General Biology*, Sedgwick and Wilson, pp. 184–191 (yeast); *Practical Biology*, Smallwood, pp. 338–375; *Elementary Biology*, Peabody and Hunt, pp. 140–153; *Essentials of Biology*, Hunter, pp. 170–189; *The Science of Plant Life*, Transeau, pp. 234–292; *Plant Life and Plant Uses*, Coulter, pp. 360–410; *College Botany*, Atkinson, pp. 137–291.

SUMMARY

Plants in general.

Seed plants.

Spore plants.

Algae

Fungi

Lichens

Mosses

Ferns

Horse-tails

Ground-pines

Examples

pond scums, sea weeds, etc.

mushrooms, toadstools, molds

rock and bark patches

common mosses

common ferns

Fungi as typical spore plants.

No chlorophyll. Consequence.

Parasitic habit:

Result to plant itself: degeneration: dependence.

Result to other living organisms:

1. Harm to hosts

2. Destruction of food

3. Value as scavengers

Examples of fungi:

Mushrooms, some edible, cf. "toadstools "

some poisonous

harmful to timber, etc.

Mildews, cause rot in potato, etc.

Molds, attack bread, meats, cheese, etc.

Yeasts, structure, oval cells

growth, by budding

conditions for growth:

moisture

warmth

food

food, sugars

products, alcohol and carbon dioxide

uses, bread and beer

CHAPTER XVII

BACTERIA

Vocabulary

Sterilized, treated so as to kill all germs, either by heat or chemicals.

Culture medium, a substance prepared for growth of bacteria.

Peptone, soluble form of proteid.

Inoculation, intentional infection with germs.

Immunity, a condition in which the body is not affected by bacterial attack.

Indispensable, very necessary.

Bacteria are very minute, one-celled, parasitic fungous plants. There are many kinds but they are sometimes classified into three groups according to their shape.

1. Coccus forms — round
2. Bacillus forms — oblong
3. Spirillum — spiral and curved

Do not forget that certain one-celled, parasitic *animal* forms also cause disease so that when we speak of the germ or microbe, it may mean either a plant or animal parasite, but when bacteria are mentioned, only the plant forms are included. Another point to bear in mind is that not all bacteria are harmful nor are all infectious diseases due to bacteria.

Bacteria are very small, one ten thousandth to one fifty thousandth of an inch in diameter. Some are so minute that they can neither be caught by a filter nor seen by a microscope.

Reproduction. Bacteria, since they have but one cell, absorb food and excrete waste directly. Under favorable conditions of food supply, temperature, and moisture, they reproduce with enormous rapidity, so that one of these microscopic cells would, if unchecked, produce a mass of bacteria weighing 7000 tons in

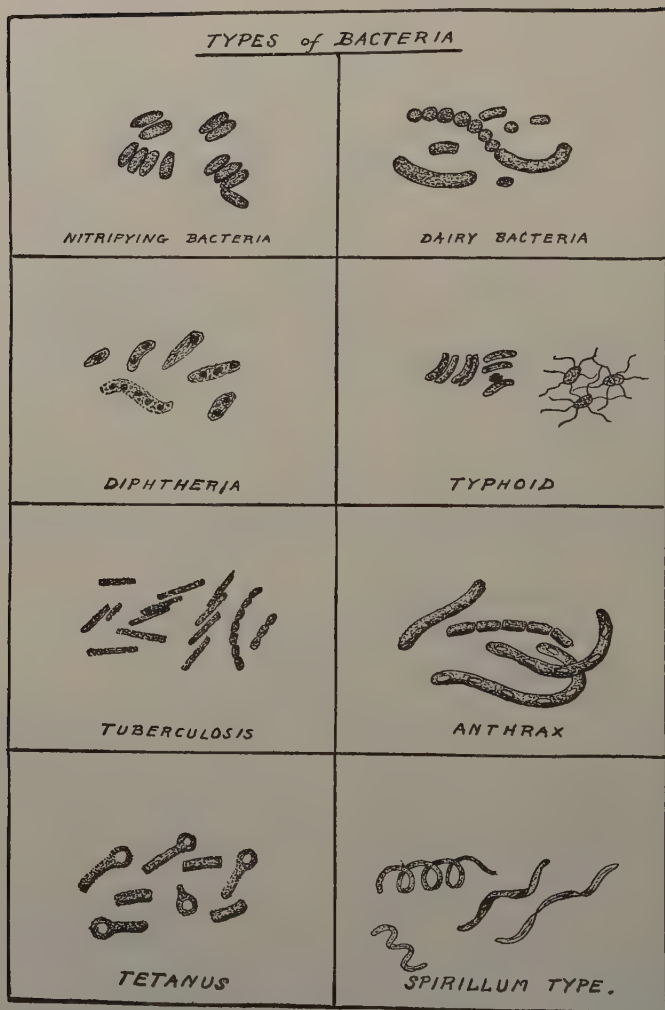


FIG. 43. Some forms of useful and of harmful bacteria. (Greatly enlarged.)

three days. Fortunately this rate is never maintained because the food supply soon becomes exhausted, or their own excreted waste matters check their rapid growth. The tuberculosis bacterium divides every thirty minutes; compute the possible number produced per day.

Occurrence. Bacteria are found almost everywhere in air, water, soil, food, inside plant and animal bodies whether dead or alive, wherever they can find food and suitable living conditions. It is fortunate that most of this host of one-celled neighbors are either harmless or useful.

The study of bacteria is called bacteriology. It is a science in itself. The methods used in its study are interesting.

Sterilization. In the first place all dishes and apparatus used are *sterilized*; that is, they are heated or treated with chemicals so as to kill any bacteria that might come from the air or water.

Making the "Medium." Then a "culture medium" is made from some jelly-like substances such as gelatin or agar, with which beef extract or some similar food is mixed and often peptone and soda are added to make it easier for the bacteria to get their nourishment.

Inoculation. This culture medium is put in sterile dishes and again sterilized several times by heat to kill any bacteria that might be present; the dishes are plugged with sterilized cotton which will keep other bacteria from getting in. Now we are ready for the next step, called exposure, or *inoculation* of the cultures. This is done by pouring upon the surface of the culture, a small amount of the milk or water to be tested, or by exposure to the air in the room where the bacteria are to be studied. Touching with the fingers, exposure to dust, and various other means will permit access of bacteria if any be present.

Growth of Cultures. After exposure, the dishes are again covered and set in a warm place for a few hours. We know that the culture was sterile, i.e., had no bacteria in it, and we know that conditions favorable to growth are provided. As a result if any bacteria have been brought in contact with the culture they soon multiply so greatly that a spot or colony develops on the gelatin.

Pure Cultures. Thus the number and kind of bacteria to be found in the substance tested can be determined. Other gelatin can be inoculated from some *one kind* of colony forming a *pure culture*, so that further study can be made and slides can be prepared for use under the microscope.

When our mothers "put up" canned fruits or vegetables at home, they go through the first part of this same process. They boil the cans, covers, and rubbers, which sterilizes them. Then they fill them while still hot with the fruit, which has been sterilized by cooking; and finally seal the cans to keep any other bacteria from getting in and causing the contents to ferment or "work."

Useful Forms of Bacteria. Do not forget that bacteria do not always mean disease, for as a matter of fact, there are many kinds, without which we could not live. If we pull up a clover plant, there are usually found attached to its roots, numerous small round bunches, called *tubercles*. These are the homes of millions of bacteria which have the ability to take the free nitrogen of the air and combine it into soil compounds which other plants can then use. These nitrogen compounds are absolutely essential to life. No other plant forms can manufacture them from the air. Therefore we see how important these bacteria are in keeping up the fertility of the soil. Nitrifying bacteria are found on the roots of all members of the clover family, such as peas, beans, and alfalfa. It had long been known that plowing under a crop of clover made the soil better for the other crops, but the reason was not understood till the nitrifying bacteria were studied.

Other helpful bacteria are those which, like fungi, aid in decay and therefore act as scavengers, removing harmful waste, and returning it to the soil as plant foods. This process is utilized in sewage disposal systems, where certain bacteria act on the city's sewage — changing it to an odorless and valuable fertilizer instead of a dangerous and expensive waste product.

The souring of milk, the making of butter and cheese, the "ripening" of meats, and the fermentation of vinegar, sauer kraut, and ensilage, are some food processes in which bacteria are indispensable. The separation of hemp and flax fiber from the

rest of the plant and several steps in the tanning of leather, curing tobacco, and preparing sponges, are other processes which depend on bacteria.

Harmfu Bacteria. On the other hand, tuberculosis, which causes one-seventh of all the deaths in the world, is due to the attack of a bacterium. At least fifty per cent of all deaths are due to this and other bacterial diseases, of which the following is a partial list.

tuberculosis	tooth decay	anthrax
erysipelas	pneumonia	cattle fevers
leprosy	ptomaine poisoning	grippe and colds
syphilis	typhoid fever	lockjaw (tetanus)
diphtheria	eye diseases	cholera
	whooping cough	

Often when bacteria attack nitrogenous foods, poisonous substances, called *ptomaines*, are produced. These sometimes cause illness or death when such food is eaten. Some serious plant diseases or "blights" are caused by bacteria and result in great crop losses. Bacteria were discovered by Pasteur in his reaserches along this line.

Defences against Bacteria. With this formidable list in view, it is evident that we ought to know how to prevent these bacteria from attacking our bodies and how to combat and destroy them when they obtain a foothold in our systems.

Skin. Our first line of defence against these ever-present enemies is our skin, and the mucous membranes which line the inside of the body. If they are clean, whole, and healthy, few bacteria can get inside our defences.

NATURAL RESISTANCE

If they break through this outer breastwork, the bacteria have to face the second line of defence, which is the natural resistance of a healthy body to any harmful invader. This second line is defended by the white corpuscles in the blood, which actually devour some of the disease germs, and also by antitoxins, which overcome the poisons made by the bacteria, and which are produced

in the blood by the presence of the bacteria themselves. Thus the attack tends to produce a defence against itself, if the body be healthy. This natural resistance to disease is called *natural immunity*, and constantly protects us from germs of whose presence we are entirely unconscious.

To provide conditions favorable to resist disease it is evident then that general good health is essential, aided by cleanliness, pure and abundant food, light, air, and whatever will keep each cell of our body keyed up to repel the invader before his rapid increase gives him the advantage. We know how often when the body is "run down," diseases are contracted, which would otherwise be fought off without our knowing that the bacteria had attacked us. How often a "mere cold" develops into some serious ailment, because the cold, though perhaps not regarded as serious, lowers the resisting power of the body and then bacteria find entrance and overcome our physiological garrison.

Defence by Antitoxins. In case the bacteria do find lodgment in our bodies, there is usually a period of some days between the time of exposure and the actual illness: this period of incubation is the time in which the bacteria are overcoming the body's first resistance and multiplying sufficiently to gain the advantage. Then the colonies of bacteria develop in some organ, — as when diphtheria bacteria attack the throat. The throat is not the only portion harmed, for the bacteria also secrete a poison (toxin) which causes more serious trouble to other organs of the body. If the patient recovers it is because his body has been able to gradually increase the amount of *antitoxin* in his system and so overcome the poisons produced by the bacteria which are causing the disease.

White Corpuscles. The lymph glands in various parts of the body produce white corpuscles, and if the body is in good condition at the time of disease attack, they greatly increase the number of these defenders. These corpuscles are able to actually "eat up" the bacteria or else carry them back to the lymph glands where they are destroyed.

Opsonins are chemical substances in the blood whose function is not thoroughly understood, but which have to do with com-

bating the attack of disease germs, by making them more susceptible to the white corpuscles. It seems as if the opsonin in the blood can be increased by the injection of dead germs, and this method is sometimes used to produce immunity to certain diseases.

Acquired Immunity. In some diseases, it seems as if the fact of having had the attack and successfully overcoming it, had provided the body with such ability to supply that particular antitoxin that the person seldom has the disease again, as for example in the case of measles and whooping-cough. The body has been trained, as it were, to oppose that kind of attack and this is called a condition of "acquired immunity."

ARTIFICIAL PROTECTION

Vaccination. From this it follows that if one has a mild attack of a serious disease, he may develop sufficient antitoxin strength to oppose the dangerous form, somewhat as a sham battle prepares the soldier to protect himself in the real engagement. This fact is the basis of vaccination which is the inoculation of a well person with a mild form of smallpox, by which he becomes able to resist the attack of this terrible disease. (Smallpox is due to a one-celled animal germ, not a bacterium.) In a similar way protection is obtained against typhoid fever and hydrophobia. Weak doses of the toxins of these diseases are administered, so that the body gradually increases its antitoxin defences and becomes immune to fatal attack. Some people oppose vaccination because when improperly performed, other germs are introduced and serious illness follows but this is a very rare occurrence. Before vaccination was practiced 95 per cent of all people had smallpox, thousands died and all were scarred for life. Then it was one of the plagues of the world, whereas it is now one of the rarest of diseases.

Antitoxins. Another method of helping our bodies to repel germ attack is by administration of the antitoxin directly. In vaccination the body learns to make its own, but there are cases where a child is too weak to do this and the actual antitoxin is

used. This is especially true in treatment of diphtheria. This antitoxin is obtained from horses, which have acquired immunity by having been inoculated with frequent doses of the diphtheria toxin, till their blood has an excess of antitoxin, which may then be drawn off, prepared and injected into the system of the patient early in the attack, thus supplying more antitoxin than the child might be able to produce in its own cells even after days of illness, if at all.

Another dreadful disease which is successfully treated in this way is tetanus or lockjaw. This is a frequent result of wounds in which dirt gains entrance, such as Fourth of July pistol injuries, and cuts on the feet, which are apt to be infected from the soil. It is not the fact that the nail is *rusty* which makes it dangerous to step on, but that a rusty nail generally is a dirty nail, and may infect with disease.

Germicides. Other means of destroying bacteria are by the use of *antiseptics*, and disinfectants which are chemical substances that destroy or hinder the growth of disease germs. Some valuable antiseptics which should be used, even in small wounds, are iodine, hydrogen peroxide, alcohol, ichthyol ointment, 4 per cent solution of carbolic acid or 10 per cent solution of potassium permanganate. Boric acid, camphor, thymol, and even common salt are useful in some cases.

Disinfectants are chemicals used to kill germs outside the body, as in case of clothing, utensils, bedding, and rooms that have been occupied by persons ill with infectious diseases. Bichloride of mercury, a dangerous poison, is valuable for disinfecting the hands or washing woodwork; dilute carbolic acid may be used for the hands, clothing, or bedding. Formaldehyde solution may be similarly used, though sometimes injurious to the skin; several coal tar products such as cresol, lysol, cresoline, etc., are said to be as efficient as carbolic acid, and less dangerous. For outdoor disinfection of cesspools, garbage cans, or privies, chloride of lime, or freshly prepared milk of lime, may be used, the former being especially useful in typhoid fever. To disinfect a room following infectious disease, all woodwork should be thoroughly scrubbed with

soap and water, walls re-papered or calcimined if possible, bedding either sterilized or burned and the room tightly closed and fumigated. For this purpose formaldehyde gas is best and may be prepared by burning a formalin candle, boiling a strong solution of formalin, or by adding permanganate of potash crystals to the solution in the proportion of one-half pound of crystals to each pint of formaldehyde. While not so efficient, and also likely to bleach colored furniture, burning sulphur produces a gas which is a useful disinfectant. One or the other of these substances should always be used in rooms where an infectious disease has occurred.

Germs, both bacteria and animal forms, are mostly killed at boiling temperature. Drying checks their growth and direct sunlight destroys them rapidly. When we cook our foods, we not only make them more digestible and attractive, but sterilize them as well. Milk may be freed of the most dangerous bacteria by pasteurization, which means heating to a temperature of from 140 to 150° F. for a period of 30 minutes. After pasteurizing it must be quickly cooled and kept closed and cool, or other germs will find entrance.

This brings us to another way in which bacteria do harm to man: they attack his foods, causing them to sour, ferment, or decay. Cooking and canning are two ways which have been mentioned of preserving food from bacteria. Meats are protected by canning, cold storage, salting, smoking, pickling, etc.; fruits and vegetables may be canned, dried, or pickled in vinegar and spices which are really antiseptics. Other more active antiseptics have been used to preserve foods, such as borax, formalin, salicylic acid and benzoate of soda, but, while they kill the bacteria, they also harm the person using the foods, and so have mostly been forbidden by law.

Development of Bacteriology. Our knowledge of the action of bacteria dates back only about forty years, but during this time great headway has been made in their control. Pasteur discovered the relation of bacteria to fermentation about 1860 but it was not until 1880 that their connection with human disease was established. Pasteur's great work against rabies — mad dog poison — was done about 1885 and now only one per cent of the victims die, instead of practically every one, as formerly. In 1894 Von Behring

and Roux developed the antitoxin for diphtheria. In the United States, deaths from this cause have decreased from 15 to 2 per 10,000 of population — in fact 98 per cent will recover if treated within two days. In similar ways we are learning to control typhoid fever, tetanus, influenza, and pneumonia. Our knowledge of the means of transmission of disease has led to *preventive* measures even more efficient in preserving human life.

Another result of modern investigation is the cheering fact that no germ disease is hereditary. You may inherit low resistance to germ attack, but if precautions are taken to increase this resistance and avoid infection, you need not suffer from the disease.

	Vaccination	Anti-toxin treatment
Method	Mild or dead germs introduced into body	Serum of blood from immune animal introduced into body
Result	Body reacts and forms its own anti-toxins	Anti-toxins directly supplied
Duration	Immunity develops slowly but persists longer	Immunity provided at once but for only the one case
Diseases treated	Small-pox Typhoid fever Rabies	Diphtheria Tetanus Meningitis

COMPARISON OF PASTEURIZING AND BOILING MILK

	Boiling	Pasteurizing
Temperature	212 deg.	140–150 deg. (30 min.) or 160–165 deg. (1 min.)
Effect on bacteria	All killed, both harmful and useful	Most harmful ones killed Useful ones unharmed
Effect on taste	Changed Less palatable	Unchanged
Effect on food value	Much reduced Less digestible	Unchanged, except vitamines

BACTERIAL ATTACK AND CONTROL

Point of Attack	Disease caused	Means of control
Food via digestive organs	Typhoid Cholera Dysentery	Cook foods, destroy flies Secure pure water supplies Pasteurize milk, keep food cold and clean
Air via lungs	Tuberculosis Pneumonia Measles, mumps Whooping cough	Avoid dust, check "colds" Anti-spitting laws Quarantine laws, avoid contact with sick Good food, sleep, general health
Skin via wounds	Blood poisoning Tetanus, syphilis Pus infections	Cleanliness Use of antiseptics and disin- fectants Protect from further bacterial attack
Foods or skin via insect trans- mission	Typhoid Malaria Yellow fever	Destroy breeding places Drainage Cleanliness, screens, etc. See Chapter 25 on "Insects and Diseases"

COLLATERAL READING

Civic Biology, Hunter, pp. 130-157; *Primer of Sanitation*, Ritchie, entire; *Story of Bacteria*, Prudden, entire; *Dust and Its Dangers*, Prudden, entire; *Drinking Water and Ice*, Prudden, look over; *Bacteria and Their Products*, Woodhead, pp. 24-47, 75-86; *Our Secret Friends and Foes*, Frankland, look over; *The Story of Germ Life*, Conn, entire; *Bacteria and Daily Life*, Frankland, pp. 35-119; *Bacteria and Country Life*, Lipman, look over, especially Chap. 2, 5, 6, 7, 13, 17, 34, 41 to 49; *Introduction to Biology*, Bigelow, pp. 256-279; *Applied Biology*, Bigelow, pp. 276-297, 554-560; *Human Body and Health*, Davidson, pp. 46-53; *Principles of Health Control*, Walters, pp. 218-346; *General Physiology*, Eddy, pp. 493-503; *Essentials of Biology*, Hunter, pp. 170-183; *The Human Mechanism*, Hough and Sedgwick, pp. 463-504; *Practical Biology*, Smallwood, etc., pp. 232-258; *Plants and their Uses*, Sargent, pp. 492-495; *The Rat Pest*, Geographic Magazine, July, 1917; *Elementary Biology*, Peabody and Hunt, Part II, pp. 10-43; *Scientific Features of Modern Medicine*, Lee, pp. 64-79; *High School Physiology*, Hewes, pp. 265-275; *Experiments in Plants*, Osterhout, pp. 361-408; *Introduction to Botany*, Stevens, pp. 256-263; *Nature Study and Life*, Hodge, pp. 457-477; *Practical Biology*, Smallwood,

pp. 343-353; *Scientific Features of Modern Medicine*, Lee, pp. 86-109; *Community Hygiene*, Hutchinson, pp. 233-247; *Handbook of Health*, Hutchinson, pp. 286-313; *Immune Sera*, Bolduan and Koopman, look through; *Infection and Immunity*, Sternberg, look through; *General Biology*, Sedgwick and Wilson, pp. 192-201; *General Science*, Caldwell and Eikenberry, pp. 79-101

SUMMARY

Definition: minute, one-celled, parasitic, fungous *plants*.

Kinds, coccus (round); bacillus (oblong); spirillum (spiral).

"Germ or microbe" may be either plant or animal forms.

"Bacteria" applies only to plants.

Characteristics:

Size.

Rate of reproduction (why limited).

Favorable conditions: food, moisture, warmth.

Occurrence.

Methods of Study.

1. Sterilization of apparatus (why necessary).
2. Making of "culture medium" (a sterile, moist food supply).
3. Inoculation with forms to be studied.
4. Growth of bacterial "colonies," on the medium.
5. Selection, and making of "pure cultures."

(Explain precautions taken in canning fruits.)

Useful forms of Bacteria.

1. Nitrogen fixers on clover roots (why useful).
2. Scavengers and decay producers (why useful).
3. Forms necessary in following processes:

Souring of milk, making of cheese.

Fermentation of alcohol, vinegar, etc.

Tanning leather.

Preparing hemp and flax.

Harmful forms of Bacteria.

(See list of bacterial disease in text.)

One-half all deaths, one-seventh by tuberculosis.

Those causing food decay. Plant blights.

Natural defences against bacteria, etc.

1. Skin and mucous membranes (clean, whole and healthy).
2. Natural bodily resistance, secured by
 - General good health.
 - White corpuscles (destroy germs).
 - Antitoxins (oppose bacterial poisons).
 - Opsonins.

Stages in bacterial attack.

1. Incubation (overcoming bodily resistance).
2. Rapid growth of bacteria.
3. Secretion of toxins by bacteria.
4. Secretion of antitoxins by blood.
5. Struggle between body and bacteria.
6. Acquired immunity in some cases.

Artificial Protection.

1. Vaccination (smallpox and typhoid).
Body resists mild attack, makes own antitoxins.
2. Antitoxin treatment (diphtheria and tetanus).
Antitoxins developed in other animals (horse).
Directly administered where body is not able to make its own.

Germicides (germ killers).

Antiseptics (used mainly in contact with body):

Hydrogen peroxide	Alcohol
Carbolic acid, 4 %	Ichthyol
Boric acid	Potassium permanganate, 10 %
Camphor	Thymol, salt

Disinfectants (used mainly outside the body):

Bichloride of mercury	furniture, hands
Carbolic acid, 4 %	clothing, hands, etc.
Formaldehyde	rooms, clothing
Creosol, lysol, etc.	clothing, etc., as directed
Chloride of lime,	garbage, refuse, etc.

Germes also killed by

Heat, as in boiling and cooking, pasteurizing

Sunlight

Hindered by dry conditions

Pasteurizing

Heat to 140–150 degrees

Cool quickly

Exclude other bacteria

Kills most harmful bacteria, does not change milk

To Disinfect a room:

1. Clean all woodwork with soap and water
2. Refinish the walls if possible
3. Disinfect furniture and bedding (see above)
4. Fumigate with
 - Formaldehyde
 - Formaldehyde and potassium permanganate
 - Burning sulphur (danger of bleaching)

Development of Bacteriology.

Pasteur, 1860–1880

Von Behring, 1894, diphtheria

Roux, 1894, diphtheria

CHAPTER XVIII

PROTOZOA

Vocabulary

Protozoa, "first animals," that is, simplest in structure: one-celled.

Microscopic, minute, so small as to be seen only with microscope.

Fission, reproduction by division into two parts.

Conjugation, reproduction by union of parts of the nucleus.

Stagnant, not flowing, as applied to water.

Vacuoles, bubble-like cavities in protoplasm, used in excretion.

In the study of plants we have seen how various forms start in a one-celled stage, the egg, and develop into very complicated forms with separate tissues of various kinds of cells. We have seen also that there are plants so simple that they never have more than one cell, in which is performed all the functions necessary to the plant. With animals the same conditions are found; there are the very complex types such as birds, insects, and man where each function has many sorts of cells (tissues) concerned in its performance — while at the other extreme, there are simple one-celled animals, all of whose life functions are performed in their single, microscopic cells.

These simplest forms are called the protozoa (first animals) and though vastly numerous and widely distributed, they are not familiar because of their small size. Small as they are they are very important in nature, forming food for higher animals, acting as scavengers, causing disease in a few cases, and even forming layers of the earth by the deposit of their countless shells, as in the case of the chalk-making forms.

Amœba. One of the simplest of these simple animals is the amœba which lives in the slime at the bottom of most streams and ponds. Though barely visible to the naked eye, under the

microscope it is seen to consist of an irregular mass of jelly-like protoplasm without even a cell wall, hence its body (the one cell) constantly changes shape, with a sort of flowing motion. A nucleus may be seen as well as tiny particles of food which are scattered through the protoplasm, and also a bubble-like cavity (vacuole) which expands slowly and then contracts suddenly, forcing out its

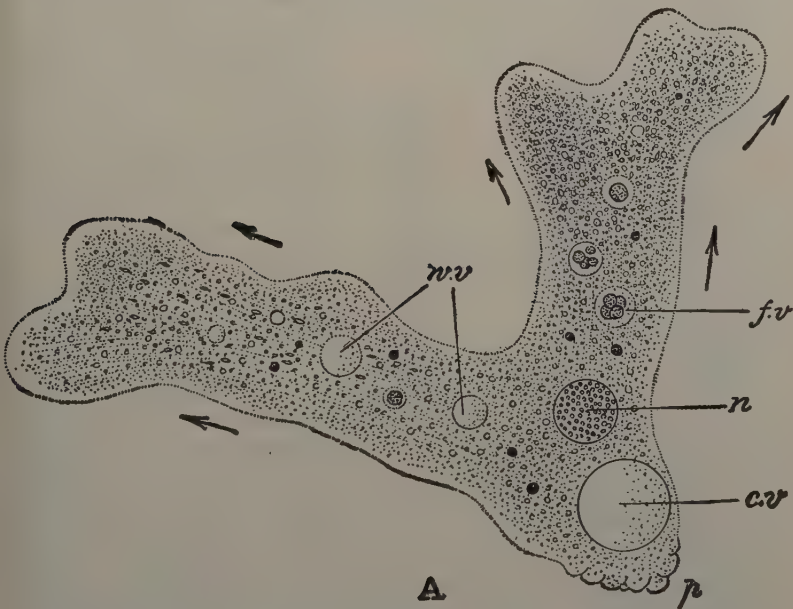


FIG. 44. *Amoeba proteus* in active moving condition. *c.v.*, contractile vacuole; *f.v.*, food vacuole; *n*, nucleus; *p*, remains of former pseudopodia. *w.v.*, water vacuoles. The arrows indicate the direction of protoplasmic flow. (Sedgewick and Wilson.) From Calkins.

contents. Simple as is its structure, one learns to look with respect and interest upon an animal which with so little material, can yet perform all the functions necessary to any organism, however complex.

The amoeba obtains food by extending lobes of its protoplasm and actually flowing around each particle. Digestion and as-

similation go on directly in contact with the food, and undigested particles are merely left behind when it flows away from them or they pass out through any part of the cell. Oxygen is taken by contact from the water in which it is dissolved and combines directly with the food and protoplasm producing energy, just as in all living things. The contractile vacuole acts as an excretory organ, getting rid of waste. Locomotion is secured by the flowing

STAGES IN REPRODUCTION (FISSION)

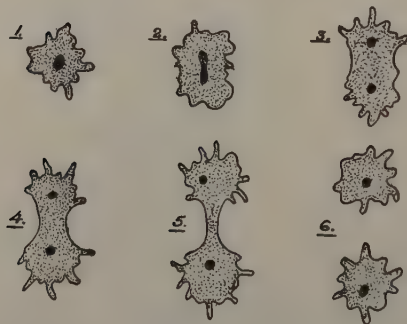


FIG. 45. Progressive stages of fission of amoeba. After Schultz.

of the protoplasm, projections being pushed out on one side and withdrawn on the other. Some form of sensation must be present because it responds to light, food, moisture, or sudden jars.

Reproduction occurs as soon as growth reaches a certain size. The nucleus first divides in two similar portions, then the rest of the protoplasm gradually separates in two masses,

each with a nucleus and capable of independent life and growth. This simple reproduction by mere division is called *fission*. Reproduction by union of anything like the sperm and egg cells of plants and other animals has never been observed in the amoeba, though it seems almost necessary that there should be some such process.

There are nearly a thousand close relatives of the amoeba, some of which attach a protective covering of tiny sand grains to their body; others secrete a layer of flint or lime. These shelled protozoans are so abundant in the tropical seas that they tinge the water white and their shells, falling to the bottom, make deposits of limestone, such as the chalk cliffs of England.

Paramecium. Another common protozoan is the paramecium which is also abundant in stagnant water. We cultivate it in the laboratory by putting some dry hay or leaves in water and leaving

them in a warm place for a few days. When observed the liquid will be found to be swarming with various kinds of protozoa, of which many are paramœcia. Their appearance is due to the fact that most protozoa can live in a dried condition and so are blown around like dust. They become attached to the hay or leaves and only await moisture and warmth to begin active life again. This is not reproduction but only a resting stage to carry them over unfavorable periods.

Structure. The paramœcium has a cell wall which gives it a definite oval shape. There is also a funnel-shaped cavity on one side which acts as a mouth. The cell is covered with tiny hair-like *cilia* by which the paramœcium swims rapidly and also paddles food particles toward the mouth cavity. Inside the cell there are, of course, the protoplasm, nucleus, and contractile vacuoles. The latter are two in number and situated in definite places at the two ends of the cell.

Specialization. Now you can understand that while the paramœcium and amœba perform similar functions, still, the paramœcium is much more fully adapted for them, in so much as it

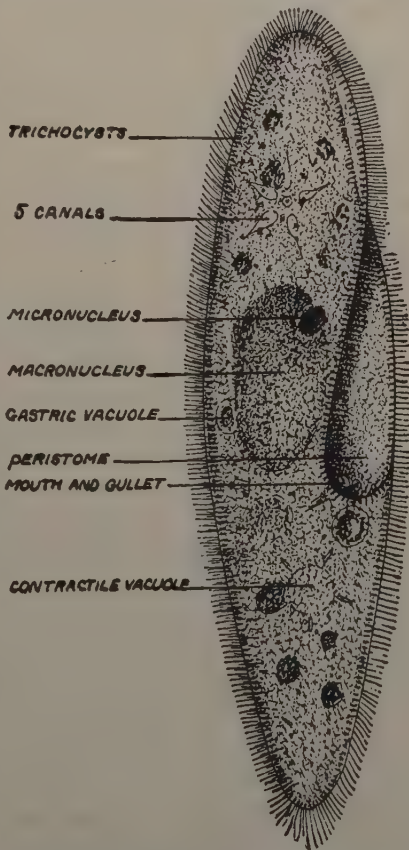


FIG. 46. Diagram of structures of *Paramecium caudatum* from an individual about 125 of an inch in length. From Calkins.

has a fixed shape; cilia for locomotion and food-getting; a definite mouth and gullet, and definite regions for excretion. This increase in adaptation of structure to function is called specialization, or division of labor, and is the mark of higher development in any plant or animal.

Reproduction. In paramœcium this function is more highly developed than in amœba and consists of two processes, fission and conjugation. Fission takes place, preceded, as usual, by the division of the nucleus, and two new individuals are produced, much as in amœba, but in a more definite manner. This process can go on for only about 150 times, when the vitality seems to be reduced and conjugation takes place.

In conjugation, two paramœcia unite by joining the region near the "mouth" cavity, and their cell wall becomes thin at the point of union. Complicated divisions take place in the nucleus of each and finally a stage is reached where there are two parts to each nucleus, one of which is stationary and the other not. The two movable nuclei now exchange places, passing through the protoplasm of the cells and finally unite with the stationary nucleus of the opposite individual. After this exchange and union of nuclei the paramœcia separate again. There has been no gain in numbers but the vitality of the protoplasm has been increased so that reproduction by fission can go on again.

This conjugation does not make more individuals as true reproduction does, but it enables both participants to reproduce by fission and is the first step toward fertilization in animals, which, as in plants, is the union of two different cells from two individuals.

Parasitic Protozoans. Some protozoans are parasitic, attacking other animals and producing serious diseases, much as do the bacteria. They are often classified with the latter as "disease germs" or "microbes." If we realize that these terms include both one-celled parasitic plants (bacteria) and one-celled parasitic animals (protozoa) then their use is correct.

Some diseases caused by protozoan parasites are in the following list. The way in which they are transmitted will be more fully discussed under insects (Chapter XXV).

malaria	sleeping sickness	cattle fever
smallpox	dysentery	trachoma
yellow fever	scarlet fever	bubonic plague

COMPARISON OF AMŒBA AND PARAMŒCIUM

	Amœba	Paramœcium
Form	Variable	Constant
Cell wall	None	Present
Locomotion	Flowing lobes	Cilia
Speed	Slow	Rapid
Food	Absorbed at any point	Definite region of absorption
Reproduction	Fission	Conjugation and fission

COLLATERAL READING

Elementary Text (Zoölogy), Colton, pp. 286-306; *Elementary Text (Zoölogy)*, Linville and Kelley, pp. 280-291; *Elementary Text (Zoölogy)*, Davenport, pp. 280-288; *Elementary Text (Zoölogy)*, Galloway, pp. 154-162; *General Zoölogy*, Herrick, pp. 24-35; *Lessons in Zoölogy*, Needham, pp. 9-21; *Practical Zoölogy*, Davison, pp. 178-184; *Animal Life*, Jordan and Kellogg, pp. 1-50; *Animal Studies*, Jordan, Kellogg & Heath, pp. 22-42; *Animals and Man*, Kellogg, pp. 37-48, 118-123; *Economic Zoölogy*, Kellogg and Doane, pp. 25-47; *Economic Zoölogy*, Osborne, pp. 10-35; *Applied Biology*, Bigelow, pp. 300-319; *Biology Text*, Peabody and Hunt, pp. 164-176; *Practical Biology*, Smallwood, pp. 45-62; *Life and Her Children*, Buckley, pp. 14-32; *Animal Life*, Thompson, pp. 210-221; *Life in Ponds and Streams*, Furneaux, pp. 99-113; *Protozoa*, Calkins, entire¹; *Proto-Zoölogy*, Calkins, entire¹; *General Biology*, Sedgwick and Wilson, pp. 192-201.

See also references on "Insects and Diseases."

¹ Look through, note pictures especially.

SUMMARY

All living things start in one-celled stage.

Sperm and egg cells in higher forms.

Bacteria: one-celled plants.

Protozoa: one-celled animals

Protozoa (first animals):

1. Characteristics,

Minute size, numerous, widely distributed.

One-celled, simple structure.

PROTOZOA, ETC.

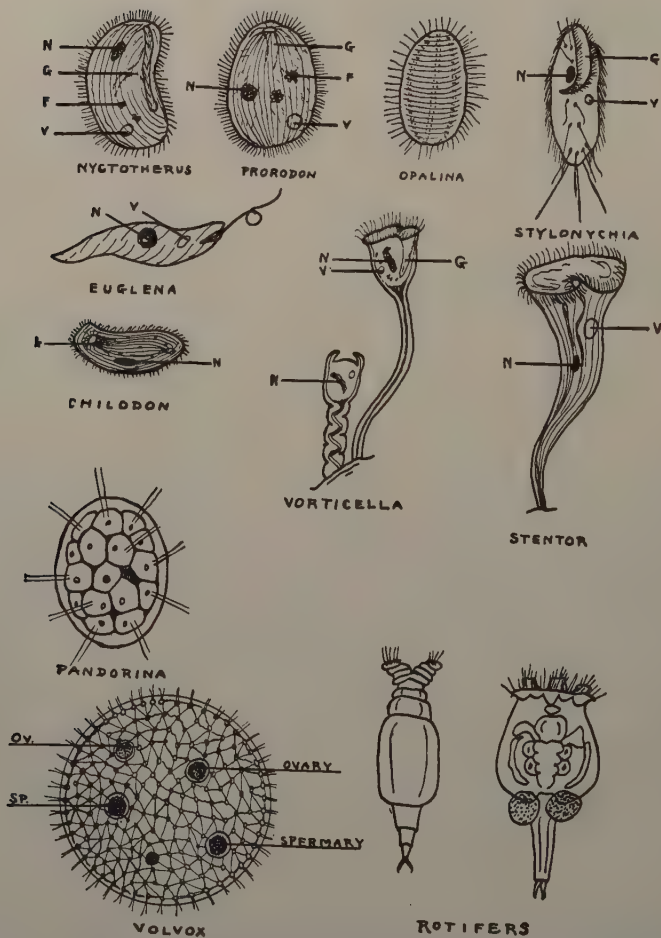


FIG. 47. Various types of protozoa, rotifers, and other organisms often found in aquarium cultures. (Greatly enlarged.)

2. Economic importance,

Food, scavengers, soil and rock formation.

Producing certain diseases.

Amœba (a very simple protozoan).

Where found.

Appearance.

Structure.

Protoplasm, nucleus, lobes, vacuoles, food grains.

Paramœcium. (A more specialized protozoan.)

Where found.

Appearance. How distributed.

Structure.

Protoplasm, nucleus, cell wall, cilia, "mouth," vacuoles, food grains.

Points of advance over amœba:

Fixed shape (cell wall).

Cilia for locomotion and food-getting.

Definite mouth region.

Two definite places for excretion.

Reproduction both by fission and conjugation.

COMPARISON OF THE MEANS OF PERFORMING THE

Life Functions	in Amœba	and Paramœcium
Food-getting	By flowing lobes	By cilia
Digestion and assimilation	By contact anywhere	In definite regions
Oxidation	Contact with dissolved air	Same
Excretion	Vacuole, variable	Two vacuoles, definite
Locomotion	Lobes, variable	Cilia, definite
Sensation	Responds to heat, light, contact, moisture, etc.	Same
Reproduction	Fission	Fission and conjugation

Comparison of Fission and Conjugation

Fission (increases numbers)

1. Nucleus divides.
2. Cell divides.
3. Growth to adult size.

Conjugation (increases vitality)

1. Union of two individuals.
2. Complicated nuclear division.
3. Cross transfer of part of nucleus.
4. Union of portions of nuclei.
5. Separation of individuals.

CHAPTER XIX

METAZOA

Vocabulary

Metazoa, "animals further along," that is, in development and specialization, many-celled animals.

Specialization, development of separate organs for different functions, division of labor.

Respective, separate or individual.

Stimuli, any outside forces that affect plant or animal, such as light, heat, contact, sound, etc.

All one-celled animals are called protozoa (first animals); all those consisting of more than one cell are called metazoa (animals further along), meaning that they are more complex in structure and more specialized in function than a single-celled animal can be.

Development. No matter how complicated a plant or animal may eventually become, it started in a one-celled stage, the fertilized egg. This in turn was the product of the union of the single sperm cell with the single ovule cell. To trace the development from this one-celled stage to the highly complicated forms is too difficult at present, and forms the basis for the whole science of embryology. However, some of the steps in the process can be briefly mentioned.

A one-celled animal (protozoan) takes in food and oxygen, and excretes waste only by means of its exposed surface. If the diameter of a solid be doubled its surface area is squared, but its bulk is cubed. Hence if a protozoan increased much in size, it would reach a point where the surface was too small to provide for the bulk, and it would die. Before this point is reached, division takes place and growth begins again, up to limit of size set by the ratio between surface and bulk. This is why protozoa are so small and why they divide so frequently. The size which a cell may reach is therefore limited by the extent of its surface.

The paramœcium is much more highly developed than the amœba but a limit to its specialization and growth is soon found and a stage is reached where further specialization in function or increase in size is no longer possible. If further advance is to be obtained, larger and more complicated forms must develop. Suppose that when a protozoan divides, the cells did not separate but remained attached, grew, and divided again and again. There would soon be produced a mass of cells much larger than any single one, and with abundant surface exposed for food-getting and breathing. In such an animal the outer cells could best attend to locomotion, sensation, and food-getting, while the inner cells could carry on digestion and reproduction. Pandorina and other simple metazoans represent this stage.

If a solid mass of cells continued to enlarge, the innermost ones would be so far from contact with food and air that a limit in size of the mass would be reached, just as with the single cell. To meet this condition, the next higher forms consist of *hollow spheres* of cells, thus giving an inner and outer surface, and permitting much larger and more complicated forms. Volvox is a representative of this condition. It consists of thousands of cells, is large enough to be visible to the eye, and has very highly developed reproductive and locomotor cells.

A hollow sphere cannot increase indefinitely in size as the single cell layer would not be strong enough, so in the next higher forms an infolding of the wall takes place, much as a hollow rubber ball can be squeezed into a cup-shaped form. Its walls will now be double with a space between them, in which a third cell layer develops. This three-layered stage is reached in the simplest sponges, and from the three layers develop all the tissues of higher forms.

It is important to remember that every plant and animal began life as a single cell, the fertilized egg. This by repeated divisions passed through the stages just described, developed from a mass of unspecialized cells into higher forms with tissues and organs. Finally it reaches its destined stopping place whether in the simple volvox or the complicated insect, bird, or man.

Specialization. Robinson Crusoe on his desert island had to perform all the processes needed to supply his wants. He had to catch and prepare his food, make his clothes and shoes, build his house and defend himself against enemies. Even though he became somewhat skillful at all these duties he could never hope to excel in any. He was, in fact, in the position of the protozoan where all the life functions are performed by one cell. Even though that cell be highly developed as in paramœcium or vorticella, still its limit of advance is soon reached.

Now, if there had been ten men shipwrecked with Crusoe, it would have been possible for one to get food, another to prepare it, others to build houses and so on. The increase in numbers permitted division of labor. This is precisely the case with such forms as volvox and all higher types; the increase in the number of their cells makes possible a separation of life functions, which is actually division of labor among cells.

To return to the desert island again, if one man continued making shoes or another did all the building, each would soon acquire skill and perform his duty better; he would have become a specialist in his line. Cells also are able to perform their functions better and better by constant use. Specialization is the term applied to this condition in cells as well as in men.

Finally, both cells and men would acquire special fitness for their tasks. This special fitness is called adaptation and is the permanent result of specialization. The more perfectly a plant or animal is adapted to its environment, the better is its chance to survive; hence this matter of development, division of labor, specialization, and adaptation is of the utmost importance.

Interdependence. There is, however, another phase of this matter of specialization, which cannot be overlooked. The man who devotes himself solely to the making of shoes, loses the ability to do many other necessary things. Cells and tissues which become adapted for special functions are all the more dependent upon other specialized cells for equally important services. So it comes to pass that the more highly specialized a plant or animal becomes

the more each part depends upon all the others, and the more difficult it is to replace or to do without a damaged tissue or organ. A simple protozoan can be divided and each half perform all the vital functions. Needless to say this cannot be done with higher specialized forms like the insect or bird, in which the interdependence has developed to a considerable degree.

By increase in numbers

Division of Labor is made possible,

by which

Workmen

gain

Fitness

for

Business

called

Cells

gain

Adaptation

for

Function

called

SPECIALIZATION

FIG. 48. Chart showing evolution of specialization.

Forms of Metazoans. The sponges have their division of labor confined to specialization of separate cells for various functions. The next higher group (coelenterates) which includes the hydra, coral polyps, sea anemone, and jellyfish, have cells performing similar functions grouped together in true tissues.

The next group (true worms), such as the earthworm, carry this division of labor still farther, having special digestive, circulatory, and excretory organs, of complicated structure, and a true nervous system with perhaps the beginning of a brain.

Still more complicated in structure and specialized in function are the molluscs which include clams, oysters, snails, squids, and devil fish. These have very complicated gills for breathing, heart and circulatory system much more developed, muscular and

nervous systems becoming very efficient. In some there are found eyes and other sense organs.

The arthropods, which include the lobster and crab, all insects, and spiders, constitute an enormous and highly specialized group whose adaptations we shall study in detail. Then at the top of the list come the vertebrates, including all backboned animals, fish, frog, snake, bird, cat, and man whose place at the head of the class is due, as always, to the specialization and development of the organ with the highest function, namely the brain, with its ability to think and reason.

All this increase in adaptation brings the animal in closer touch with its surroundings or environment. The amœba vaguely turns toward food and moisture, contracts if disturbed or perhaps turns away from strong light. As development progresses, response is made to other outside forces (stimuli) and we have organs for touch, taste, smell, hearing, and sight, all of which enable the animal to adapt its life to its environment and by that means become successful in the struggle for existence which goes on with its neighbors.

COLLATERAL READING

General Zoölogy, Linville and Kelly, pp. 292-304; *Animal Life*, Jordan and Kellogg, pp. 24-49; *Animal Studies*, Jordan, Kellogg and Heath, pp. 33-42; *Animal Life*, Thompson, pp. 143-152; *Comparative Zoölogy*, Kingsley, pp. 318-320; *Elementary Zoölogy*, Kellogg, pp. 57-63; *Essentials of Biology*, Hunter, pp. 199-210.

SUMMARY

Protozoa (first animals), one celled.

Metazoa (animals further on), more than one celled.

1. Development.

Plant and animal *begin* as single cells (sperm, ovule).

Stages of progress.

One cell.

Two cells to many in mass (Pandorina).

Hollow mass of cells (Volvox).

In-folded, hollow form, three layers (Sponges).

All higher forms, tissues from these layers.

COMPARISON OF PROTOZOA AND METAZOA

Protozoa	Metazoa
One-celled	Many celled
No specialization in simplest except the nucleus	Specialized tissues and organs
Some have a cell wall, cilia, "mouth" but no regular systems of organs	Digestive, respiratory and nervous systems
Reproduce by fission or conjugation	Reproduce by eggs and sperms
Excretion by vacuoles	Excretion by kidneys, or analogous organs, skin, and lungs
Minute size	Much larger size
No "body wall" either in embryo or adult	Three layers in embryonic body wall which develop as follows: 1. Ectoderm, forms outer skin and its appendages:— Nervous system and sense organs 2. Mesoderm, forms inner skin, fat, bone, muscle, connective tissue, serous membranes 3. Endoderm, forms mucous membranes and all organs that it lines, gills, lungs, glands

Classes of Metazoans	Degree of Specialization	Representative
1. Sponges	<i>Cells</i> adapted for food getting, digestion and reproduction	Bath sponge
2. Coelenterates	<i>Tissues</i> for the above processes and for locomotion	Hydra Jelly fish
3. Worms	<i>Organs</i> well developed, nerves, blood vessels, muscles	Earthworm
4. Molluscs	Sense organs, gills, heart, etc. more complicated	Snail Clam
5. Arthropods	Great specialization, skeleton, all senses, very active, nervous system and instinct	Insects Crayfish Spiders
6. Vertebrates	Great internal specialization, high special senses, brain, instinct, and reason, varied locomotion, skeleton	Fish Frogs Reptiles Birds Man

2. Specialization.

Beginning as single cell.

Increase in number of cells.

Separation of functions (division of labor).

Better performance of functions (specialization).

Development of fitness for functions (adaptation).

3. Interdependence.

1. Advance in development means advance in adaptation.

2. Advance in adaptation means closer contact with surroundings.

3. Both of which mean success in the struggle for existence.

CHAPTER XX

WORMS

Vocabulary

Anterior, the end toward the head, usually the end that precedes in locomotion.

Posterior, the end farthest from the head.

Analogous, having similar function.

Homologous, having similar structure or origin.

Setae, hair-like projections by which some worms travel.

Incalculable, impossible to estimate.

Degeneration, loss of ability to perform function, loss of structures due to disuse.

The worms may be taken as a class of animals showing a moderate degree of specialization. They include the common earthworm, leeches, bloodsuckers, tapeworms, horsehair worms, etc.

THE EARTHWORM

External Features. The earthworm is familiar and will do to represent the group. Its slender body is divided into rings or segments. The larger end, near which is a light colored girdle, is the head (anterior) end; while the vent, or opening of the intestine marks the opposite (posterior) extremity. Projecting from each segment are four pairs of bristles (setae) which are operated by separate muscles and are used in locomotion. The girdle secretes the case in which the eggs are deposited and near it are the tiny openings of the egg and sperm ducts, since the organs of both sexes are found in the same animal. On opening the body, the wall is found to consist of a very thin cuticle and two thick layers of muscle, one running lengthwise, and the other around the body.

Digestive System. Inside the body wall, the large digestive system can easily be recognized, there being a muscular pharynx, a

crop, stomach, and long, straight intestine, terminating at the vent.

Circulatory System. Not so conspicuous is the circulatory system, which consists of two large blood vessels, one above, the other below, the digestive tract, connected by branches in each segment. Some of these branches pulsate, acting as a heart, to drive the blood through the system. It must be remembered that the functions of any circulatory system are ones of transportation. It carries food from the digestive organs to the tissues, oxygen from the breathing organs to the tissues, and waste products from tissues to the organs of excretion. In all animals less specialized than the worm, the structure was so simple that these processes were carried on directly by osmosis, but in the worm, division of labor is more complete, the various tissues more complicated and so, for the first time, a transportation system is developed.

Excretory and Nervous Systems. Besides the circulatory organs, there are rather complicated sets of tubes in each segment, which excrete waste matter. There are two sets of reproductive glands between the pharynx and stomach. On the lower (ventral) side of the body is a double row of light-colored threads (the nervous system), united in each segment, and ending in a tiny knob near the mouth, which corresponds somewhat to the brain. When such an animal is compared with the paramœcium, it is evident that its functions have much better machinery for their performance.

Locomotion. The worm is adapted for locomotion by the body muscles and setae. The muscles extend the anterior part of the body, the setae are slanted backward and grip the soil, and the posterior part of the body is pulled forward with a sort of wave-like motion. By this means the worm travels on the surface or burrows in the ground. Burrowing is assisted by the fact that the earthworm practically eats its way, taking the soil into its digestive tract, absorbing what organic matter it can use as food, and bringing the unused earth to the surface as "worm castings." These are often seen on lawns, tennis courts, and golf greens.

Analogous Organs. Organs in different animals which perform similar functions are called analogous organs. The setae and

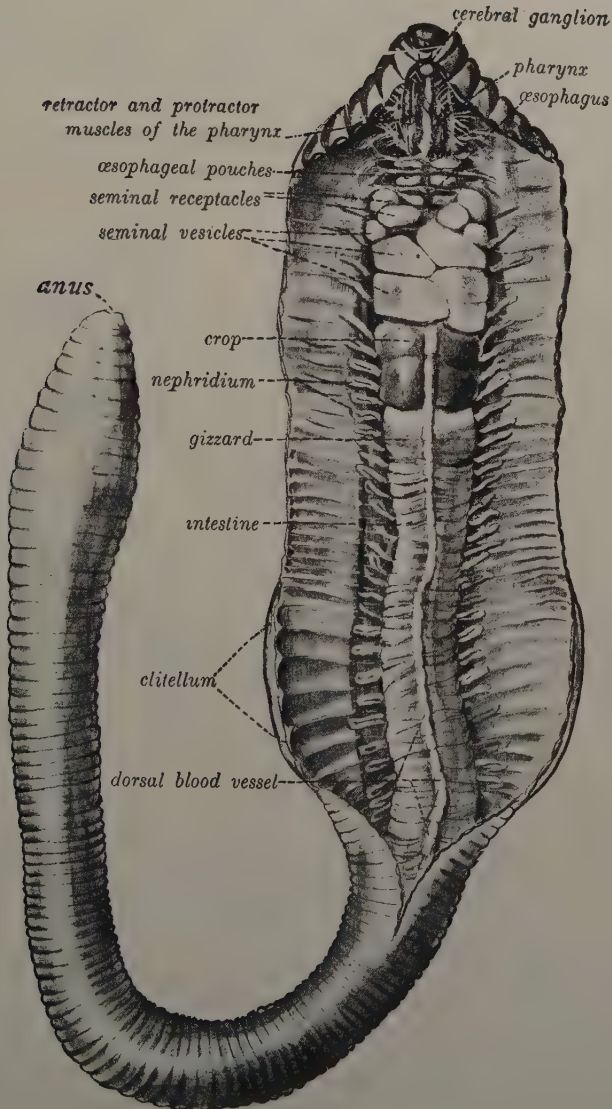


FIG. 49. Dissection of the earthworm, *Lumbricus* sp. From Kellogg.

muscles of the worm are analogous to the cilia of the paramœcium, or the flowing lobes of the amœba. (What analogous organs in fish, bird, and man?)

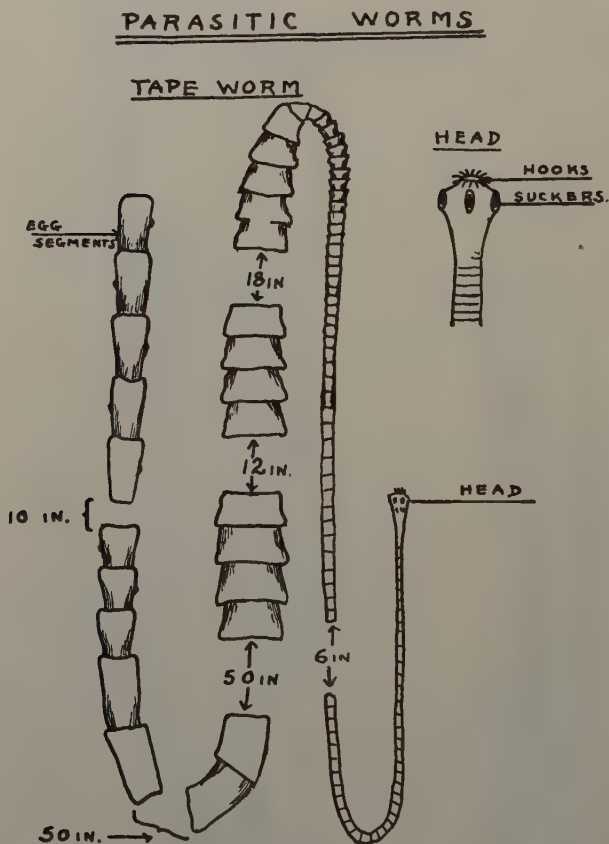


FIG. 50. Diagram showing structure of tapeworm.

Food. The food of the earthworm consists of leaves of cabbage, celery, and other plants, as well as some kinds of meat, together with organic matter found in the soil. This is gathered at night,

taken into the burrows and eaten, while the waste is brought to the surface with the earth as castings.

Economic Value. This method of feeding loosens and enriches the soil, performing about the same work as does the farmers' plow, though to a greater extent, for the worms are found in all parts of the world, in such numbers that they pass through their

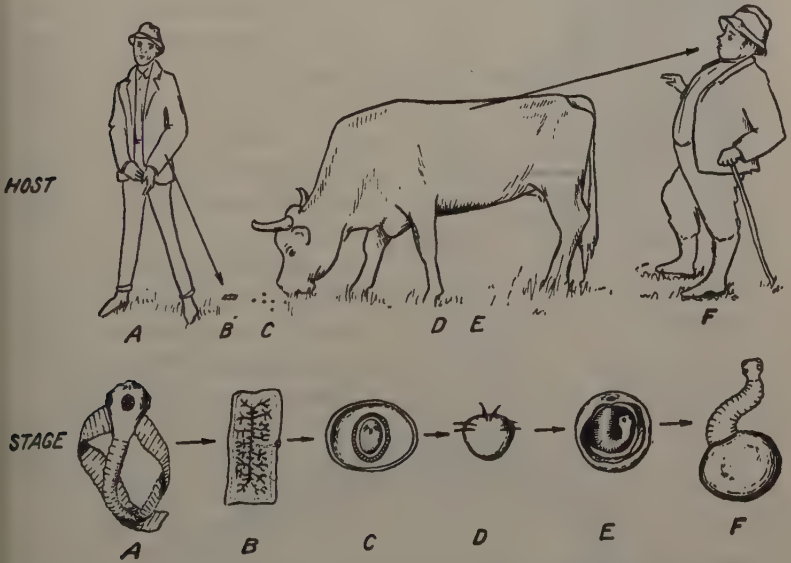


FIG. 51. Life history of beef tapeworm. A, adult tapeworm in intestine of man; B, proglottid full of eggs on ground; C, eggs on ground; D, six-hooked larva (onchopore) set free and bores through tissues of cow; E, cysticercus or bladderworm, in cow's flesh; F, young tapeworm in man. From Pearse.

bodies an average of ten tons of soil per acre, every year, and thus do an incalculable service to the farmer. Thus the humble earthworm, whose function may have seemed to be to furnish bait for fishing, now is seen to be a very useful member of society. It has, however, some very bad relatives, which do a great deal of harm and therefore require special mention.

PARASITIC WORMS

In this group are included the tapeworm, trichina, hookworm, and many others. As is often the case, they are harmful because parasitic. A parasite, as has been said, takes the nourishment of another creature instead of getting its own.



FIG. 52. Encapsuled trichinæ in trunk muscle of pig. (Greatly magnified, after Braun.) From Kellogg and Doane.

Tapeworm. The tapeworm lives first within the body of pigs or cattle, the egg being taken in with their food. It develops in the intestine, bores its way into the muscles and goes into a resting stage. If the flesh of such animals be eaten when not thoroughly cooked the development continues in the intestine of man, where the worm attaches itself by hooks on its head, lives on the digested food with which it is surrounded and by robbing its host of needed nourishment, produces segment after segment till a length of thirty to fifty feet may be attained. These segments are practically

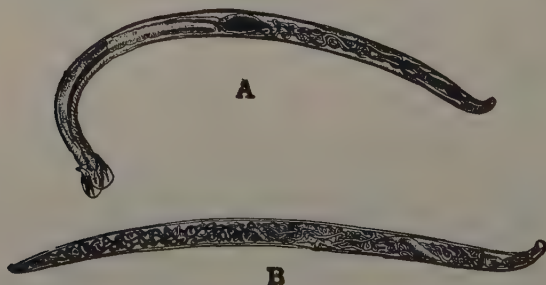


FIG. 53. Hookworm, *Necator americanus*. a, Male; b, female. (Greatly enlarged; after Wilder.) From Kellogg and Doane.

sacs of eggs which break off from time to time, allowing the eggs to escape, dry, and scatter, where hogs or other animals may eat them and start the circle over.

Trichina. Round worms are another class of parasites, of which the "vinegar eel" and the intestinal pin worms are comparatively harmless forms. The pork worm (trichina) of this same class may cause serious illness or death. These worms pass their first stage in the pig, dog, cat, ox, or horse, where they bore into the muscles, surround themselves with a coating (cyst), and remain alive but inactive. If such flesh be eaten when improperly cooked the cyst is dissolved, the worms develop, bore through the tissues again, and produce the painful and often fatal disease known as trichinosis. The tapeworm is large; usually only one is present and it does its chief harm by absorbing food needed to nourish the body. The trichina, on the other hand, is microscopic in size, vastly numerous, and produces acute disease by penetration of the tissues. Careful inspection and thorough cooking of meats are lessons to be learned from the above life histories.



Fig. 54. Section through the skin of a dog two hours after it has been infected with the Old World hookworm. (Greatly enlarged; after Wilder.) From Kellogg and Doane.

Hookworm. The hookworm is another parasite, found in the southern states, which attacks man by way of the feet and thence by way of the veins, lungs, and throat, penetrates to the intestine, where it absorbs food and causes loss of blood. This lowers its victim's strength and produces the characteristic laziness of the "poor whites" of the South. Almost all animals, from clams and insects to cattle and man, are subject to the attacks of parasitic worms. The hookworm alone costs this country about twenty million dollars (\$20,000,000) per year, in loss of labor due to its effect on health.

Note: The "horsehair snake" which you frequently find in ponds and streams has nothing to do with a horsehair, nor is it a

COMPARISON OF LIFE HISTORIES OF THREE DANGEROUS WORMS

Tapeworm	Trichina, Porkworm	Hookworm
Adult segments pass off in intestinal waste These are really egg masses	Adults produce living young, no eggs	Eggs pass off in waste
Eggs eaten by hog	Hog may get them from rats or pork in its food	Eggs hatch into larvæ in moist soil
Hooked larvæ bore into muscle making "measly" pork	Young bore into flesh and form cysts; cause disease in hog	Bore through skin of feet May get in via food
Flesh not well cooked eaten by man	Flesh not well cooked eaten by man	Penetrate into blood vessels, thence to trachea, and are swallowed
Larvæ develop into adult in intestine and attach to wall by hooked head Absorb digested food and produce eggs	Cyst dissolved and after two days larvæ bore into the muscle, causing disease If patient survives, they form cysts and are inactive	Attach to upper intestinal wall and suck blood Produce more eggs
Usually one large worm in the intestine	Numerous small worms in the muscles	Numerous small worms in the intestine
Robs body of food Interferes with digestion Lowers vitality	Causes acute painful and often fatal disease	Produces anæmia and lowers vitality
Remedy, meat inspection and thorough cooking	Remedy, meat inspection and thorough cooking	Proper disposal of body wastes, shoes Cleanliness Easily cured by simple treatment

snake. It is one of the round worms (related to the "vinegar eel" which is also not an eel) and is parasitic upon beetles, grasshoppers, and other insects, thus doing considerable good.

COLLATERAL READING

Vegetable Mould and Earthworms, Darwin, entire; *Life and Her Children*, Buckley, pp. 135-152; *Economic Zoölogy*, Osborne, pp. 67-120; *Economic Zoölogy*, Kellogg and Doane, pp. 98-105; *Elementary Text*, Linville and Kelly, pp. 195-235; *Practical Zoölogy*, Davison, pp. 150-161; *Applied Biology*, Bigelow, pp. 340-354; *Animal Studies*, Jordan, Kellogg and Heath, pp. 59-88; *Life in Ponds and Streams*, Furneaux, pp. 114-126.

See also articles under "Worms," "Tapeworm," "Trichina," "Leech" in encyclopedias.

SUMMARY

Representatives.

Earthworm, tapeworm, hairworm, vinegar eel, leech, etc. (not caterpillars).

anterior and posterior (define in notes).

dorsal and ventral (define in notes).

External Structure. Shape.

Segments, count them as far as girdle.

Girdle, function.

Mouth, call attention to pre-oral lobe. Vent.

Setae, adaptations.

1. Number.

2. Location on sides.

3. Attached muscles.

Functions of Setae.

1. Locomotion, 2. burrowing, 3. food-getting.

Reproductive openings on segments 9, 10 and 14, 15.

Both sexes in individual.

Internal Structure.

Body wall, two muscle layers, use of each. Cuticle.

(Lack of skeleton and consequent slow motion.)

Digestive system.

Mouth, manner of food-getting.

Muscular pharynx, function.

Crop, stomach, and intestine with special functions.

(Glands and schemes for increase of digestive area.)

Circulatory system.

Dorsal and ventral vessels.

Cross tubes in each segment, some pulsate.

Functions of *any* circulatory system.

Transfer of food from digestive organs to tissues.

Transfer of oxygen from lungs to tissues.

Transfer of waste from tissues to excretive organs.

Excretory organs.

Pair in each segment, well developed.

Nervous system.

Simple "brain" and ventral nerve chain.

Separate nerve branches, much higher than previous animals studied.

Locomotion:

Adaptations for,

1. Body muscles, two layers, different motions.

2. Setae with their own muscles.

3. Habit of flattening the "tail" region in burrow.

Burrowing:

Adaptations for,

1. As above.

2. Habit of swallowing earth through which it goes.

3. Evidence shown in "castings."

Food-getting:

Food, celery, lettuce, meat, etc., from surface, taken below; organic matter in soil.

(manner of eating; use of pharynx and air pressure).

Economic value:

Earthworm, loosens and enriches soil, brings up fresh earth, takes down organic matter, 10 tons per acre per year.

Reasons for development of circulatory system in higher forms.

More numerous cells.

Greater division of labor.

All tissues not in reach of food or air by mere osmosis.

Need for transportation system.

Analogous organs:

Definition.

Examples: setae, cilia, pseudopodia, all for locomotion.
similar examples from fish, bird, man, etc.

Parasitism.

Results:

Harm or death to host.

Degeneration.

Loss of organs.

Absolute dependence.

Need for vast reproduction.

} to parasite.

Tapeworm.

1. Eggs eaten by pigs or cattle.
2. Egg develops in intestine.
3. Young bore into muscles, and go into resting stage.
4. Meat eaten by man (not thoroughly cooked).
5. Development continues. Causes weakness and anæmia.
6. Head attaches by hooks, absorbs food, grows by segments.
7. Segments produce many eggs, which are scattered.

Trichina (related to vinegar worms, and intestinal worms):

1. Young bore into muscles and form cysts (in animals).
2. Uncooked flesh eaten and cyst dissolves (in man).
3. Young again bore into muscles producing disease, or death.

Hookworm.

1. Enters by way of feet, veins, lungs, throat, intestine.
2. Punctures intestines, causing loss of blood and absorbs food.
3. Lowers strength, makes susceptible to other diseases.
4. Loss in labor of \$20,000,000 per year in U. S.

Explain:

“Horse hair snakes.”

Vinegar “eels.”

“Raining down” of earthworms.

CHAPTER XXI

ARTHROPODS

Vocabulary

Segmented, made up of joints or sections.

Dorsal, the region of the back, usually, but not always, uppermost in animals.

Ventral, the side opposite the dorsal, the region of the belly, usually underneath.

Genus, next to the smallest general division in classification; plural is genera.

Species, the smallest general division in classification; plural is also species (specie means money).

The group of animals next to be studied is called the arthropods (jointed foot) because all their leg-like appendages are divided in joints or segments.

Characteristics. They are the largest group of living things in the world, outnumbering all the other species of the animal kingdom. These numerous forms all agree in the following points:

1. They have jointed appendages.
2. They have an external skeleton.
3. The body is segmented and consists of three regions,
 - (a) head specialized for food-getting and sensation.
 - (b) thorax for locomotion.
 - (c) abdomen not highly specialized.
4. Heart is in the back (dorsal) region.
5. Nervous system is beneath (ventral).

Classes. The arthropods are divided into three or sometimes four *classes*, the fourth being rather indefinite, and including the worm-like forms such as the centipedes and "thousand legs."

1. Crustacea, which include crayfish, lobster, crab, shrimp, and many others.

2. Acerata, the spiders
3. Insecta, the insects.
4. Myriapods, worm-like forms.

The members of each of these classes have all the characteristics of the arthropods, but there are additional points of resemblance within each class. For instance, all the crustacea have the head and thorax united into a cephalothorax (head-thorax) which is covered by a part of the external skeleton called the carapace. Usually they have five pairs of legs and breathe by gills attached to them.

The acerata (spiders) have no carapace, have four pairs of legs and breathe by air sacs or tracheae. The insects' head and thorax are separate; they have three pairs of legs and usually wings as well, and breathe by means of tracheae. (For further comparison see tabulation.)

Classification. Each of these three classes is further divided into groups called *orders*, the orders into *families*, and the families into still smaller groups called *genera* (singular: genus) and genera into *species* (singular: species also).

As we come down in the classification, the groups have more and more points of resemblance, but of course include fewer individuals. Take, for instance, the common grasshopper; it belongs to the

Branch of the animal kingdom called arthropods

Class, insecta

Order, orthoptera

Family, acrididae

Genus, melanoplus

Species, femur-rubrum.



FIG. 55. A centipede, *Scolopendra* sp. (From Specimen.) From Kellogg.

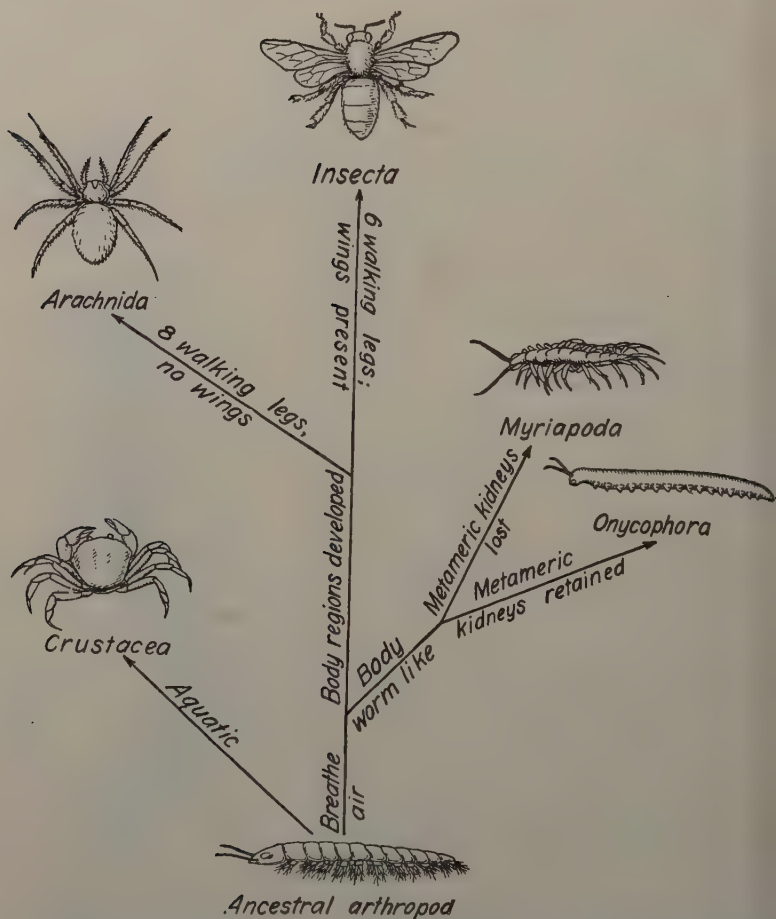


FIG. 56. A scheme to show how the arthropods have developed from their ancient ancestor. The branches are not intended to represent actual relationships but to indicate the lines of specialization which have been followed. From Pearse.

We do not have to learn these apparently difficult names. What we ought to try to understand is the *method* of classification, because it is used in all animal and plant groups and is so well il-

lustrated by the arthropods. In the case of the grasshopper, the *species* group includes just that one kind of grasshopper and no others so they are alike in all points; the *genus* includes several species with a good many points of resemblance. The *family* includes the members of several genera which resemble each other but less closely than the members of the genus. The *order*, orthoptera, includes several families with members as different as the cockroach, locust, katydid, grasshopper, and crickets, while the *class* insecta includes all the different orders of insects, such as bees, moths, flies, and beetles which of course include many individuals but resemble each other in still fewer points. As stated before, the Insecta is one of the three classes into which the arthropod branch is divided and have the characteristics of that enormous group, in common with the acerata and crustacea.

Value of Scientific Classification. This may seem very complicated but is really very necessary, for if there were no way of grouping the different forms, they could never be studied or understood, much less named and identified. Not only this, but resemblance in points of structure shows actual family relationship, those forms most alike being nearest related and those with less points in common, more distantly connected. Classification is not only a convenient arrangement to save labor in the study of living things, but shows their relationship and descent, as well.

Let us classify the grasshopper fully according to this outline, and see how much is included in merely its proper scientific classification.

Kingdom: Animal

Branch: Arthropoda (jointed-foot animals)

Class: Insecta (body "cut into" three regions)

Order: Orthoptera (straight-winged)

Family: Acrididae (locust family)

Genus: Melanoplus (black armored)

Species: femur-rubrum (red-legged)

From just the translation of the names used, one can obtain a fair description of the animal concerned, and if the characteristics

of each successive group are known, a complete description is obtained.

If a person in Africa were addressing a letter to this country, and gave a full and exact address, it would cover as many items, as the following comparison shows.

Grasshopper	Letter
Kingdom: Animal	Nation: United States of America
Branch: Arthropoda	State: Illinois
Class: Insecta	City: Chicago
Order: Orthoptera	Street: Madison
Family: Acrididae	Number: 3561
Genus: Melanoplus	Surname: Smith
Species: Femur-rubrum	First name: John J.

In the case of the letter as many items have been mentioned as with the scientific classification, and for the same purpose, namely, that both shall be absolutely definite and apply to one only. If, in addition, we could so address our letters that the appearance and relationship of the addressee were included, it would correspond to the very remarkable system of classification used in all biologic work.

Scientific Names. When speaking of a plant or animal the genus and species names are usually all that are given, assuming that the relationship to the larger groups will be known. The genus is placed first and begins with a capital letter, the species follows, and begins with a small letter unless it be from a proper name. The genus name is usually a noun and the species name an adjective; the genus name precedes the species name, as is the regular Latin order. We follow it in our lists of names in all formal records where John J. Smith would appear as Smith, John J. Thus, *Melanoplus femur-rubrum* is the scientific name of the common grasshopper. It is a long name, even for a scientific one, and was chosen on that account, but how much more convenient and accurate than saying "the black-armored grasshopper with red legs."

Another advantage of scientific names is that they are uniform

throughout the world. People of all languages use the same name for the same plant or animal in their scientific works, and as a result there is no confusion, nor any need for learning a new set of names. Common local names are always uncertain, for there are often several names for the same plant or animal. With the scientific names there is but one possible, and therefore there can be no chance for mistake.

Scientific names have these advantages:

1. They are absolutely definite.
2. They are used by people of all languages.
3. They are usually descriptive.
4. They are easier to study than separate descriptions.
5. They show relationship and descent.

COLLATERAL READING

Applied Biology, Bigelow, pp. 358-404; *General Zoölogy*, Linville and Kelly, pp. 138-156; *Animal Studies*, Jordan, Kellogg and Heath, pp. 109-129; *Economic Zoölogy*, Kellogg and Doane, pp. 106-125; *Economic Crustacea*, U. S. Fish Commission Report, 1889-1893; *Life and her Children*, Buckley, pp. 153-177; *Zoölogy Text*, Colton, pp. 54-77; *Elementary Zoölogy*, Kellogg, pp. 144-156; *Zoölogy Text*, Shipley and MacBride, pp. 118-135; *Elementary Zoölogy*, Galloway, pp. 232-265.

SUMMARY

Meaning of name: Number of members.

Characteristics:

1. Jointed appendages.
2. External skeleton.
3. Three-body regions.
 Head, food-getting and sense organs.
 Thorax, locomotion.
 Abdomen, reproduction, less specialized.
4. Dorsal heart and ventral nervous system.

Animal Kingdom divided into

1. Branches, which are divided into
2. Classes, which are divided into
3. Orders, 4. Families, 5. Genera, 6. Species.

Note:

Larger groups have fewer points in common, more individuals.

Smaller groups have more points in common, fewer individuals.

Smaller groups have all characteristics of the larger groups of which they are a part, and certain peculiar to their own.

Classes	Characteristics	Examples
Crustacea	Head-thorax united Carapace, gills Five pair legs	Lobster Crayfish Crab, shrimp
Acerata	No carapace, no gills Four pair legs Air sacs or tracheae	Spiders Horseshoe-crab
Insecta	Head and thorax separate Three pair legs; wings Breathe by tracheae	Beetles Grasshoppers Butterflies

Classification:

1. Based on likeness of structure (homology).
2. Hence shows relationship and descent.
3. Assists in study and placing of new forms.

Scientific Name:

1. Consists of genus and species names.
2. Avoids long descriptions.
3. Is universally used.
4. Makes meaning absolutely definite.
5. Shows relationship of different forms.

CHAPTER XXII

CRUSTACEA, A CLASS OF ARTHROPODS

Vocabulary

Carapace, the external protective covering of the thorax in crustacea.

Mandibles, jaw-like organs.

Maxillae, little jaws, aid in holding food.

Maxillipeds, jaw-feet, aid in catching, holding, and chewing food.

Literally, actually, truly.

Our study of the worms showed us a group of animals in which tissues and organs had become somewhat specialized, circulatory organs developed, and adaptations formed for an inactive underground or parasitic kind of life. In the crustacea we deal with animals such as crayfish, lobster, and crab, which are adapted for an active, aquatic (water) life, in which division of labor among their various organs has been carried to a higher point.

CRAYFISH

External Structure. The crayfish, which we will study as a type, has the body covered with a dark-colored, limey, external skeleton (exo-skeleton) divided into two regions, the cephalo-thorax (head thorax) being covered by the united carapace, and the abdomen made up of seven separate movable segments. This is the first animal we have studied which has had any skeleton at all and it may seem strange to find it on the outside of the body while ours is inside. However the same functions are performed in both cases, namely to protect the organs and act as levers for the muscles.

Protection is most important in the crustacea which really have a suit of mail, such as the knights used to wear. Their joints are

made to bend by the same arrangements, only better adapted than man's, and they cover their head and body by a shield (carapace) far lighter and more efficient than ever warrior carried. Not only is their exo-skeleton strong, light, and flexible, but it is colored so as to escape notice from enemies (protective coloration). It is also provided with sharp spines and projects downward at the sides, thereby guarding the gills and soft under parts of the body. In addition to its protective function, the skeleton forms a rigid

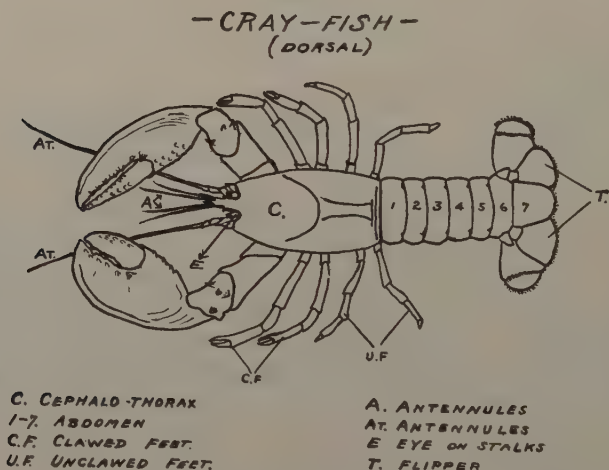


FIG. 57. The crayfish — a type of crustacea.

series of levers, by means of which a complicated system of muscles provides for swift motion and locomotion, essential for escape attack, and food-getting. The development of a skeleton has also enabled its possessor to advance in many ways.

As stated before, the body consists of segments (20 in all) though only the abdominal ones are movable, those of the cephalo-thorax being fused (united) together for greater strength and protection while the numerous appendages provide for the needed freedom of motion. Each of these twenty segments has a pair of appendages

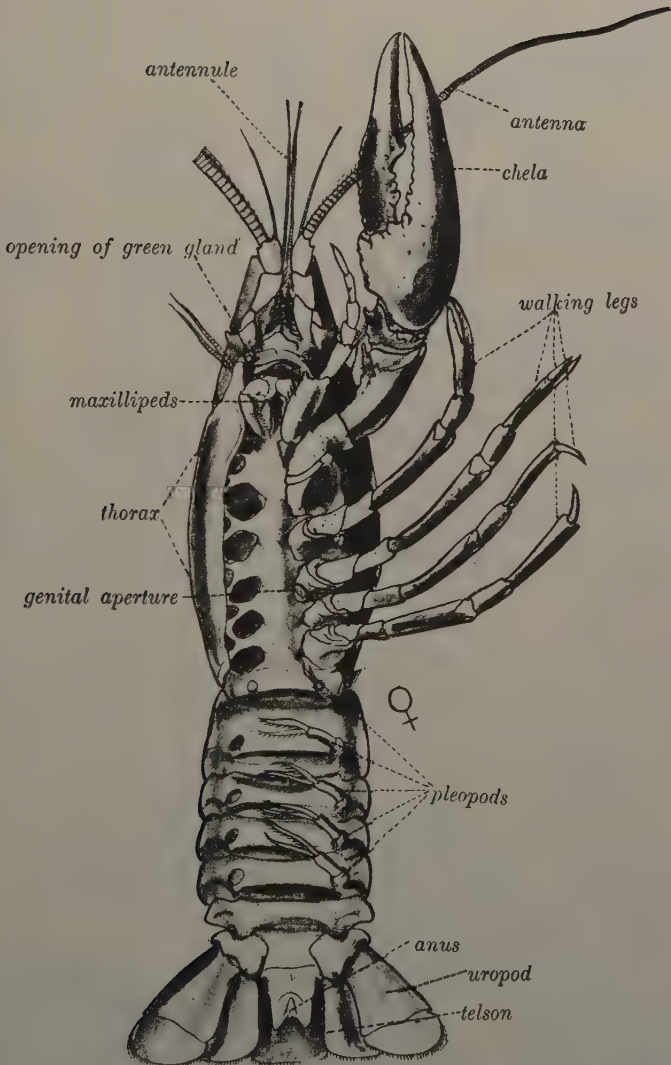


FIG. 58. Ventral aspect of crayfish (*Cambarus* sp.) with the appendages of one side disarticulated. From Kellogg.

most of which are adapted for different purposes (being developed from the ordinary swimming leg) as is shown in the tabulation. The front of the carapace extends forward into a protective beak, the rostrum (why so called?), on either side of which are the eyes, set on movable stalks and each composed of many lenses.

Head Appendages. Beginning at the anterior (head) end, we first come to the small and large feelers (antennae) at whose base open the ear sacs and excretory organs respectively. Then come the true jaws (mandibles) and two pairs of little jaws (maxillae) which aid in chewing the food. To the posterior maxilla is attached the "gill bailer," a scoop-shaped organ for paddling water over the gills, the flow being toward the anterior. So far, the organs named belong to the head. Notice the various functions performed. Also observe that the jaws work from side to side and not up and down, because they are merely leg-like appendages adapted for chewing and so continue to have a horizontal motion as do the legs.

Thoracic Appendages. The first appendages of the thorax are three pairs of maxillipeds (jaw feet) whose function is holding and chewing food. To these are attached gills for respiration. Next come the large claws, evidently for defence and food getting, then two pairs of legs with claws at the tip and two more pairs without claws. These four pairs of legs are concerned mainly with walking, and to them and to the large claws as well, gills are attached, which extend up under the carapace into the gill chamber.

Abdominal Appendages. The appendages of the abdomen are called swimmerets and are similar on the first five segments, being adapted for paddling forward in the water. They are also used by the female for attachment of her eggs. The sixth swimmeret is enormously developed into a wide fin or flipper while the appendage of the seventh segment is reduced to a mere spine and the segment itself is flattened. The sixth and seventh segments together form a powerful organ for backward locomotion, for they can be whipped forward by the strong muscles of the abdomen and the animal will shoot backward at high speed.

Adaptation. While we do not have to memorize all these appendages, there are two lessons that their study must teach; first how



FIG. 59. The appendages from the entire right side of the body of a lobster, arranged serially to illustrate serial homology. From Calkins.

remarkably division of labor may be carried out, and second that we have here the modification of *one* kind of organ for many uses. The tabulation will show how many and how varied are the functions performed. It will also be seen that these various organs are developed from a simple kind of appendage (the swimmeret). By the addition and modification of segments, organs have been developed as widely different as the large claws and the antennae.

Homology. When we find organs (either in the same or different animals) which were developed from the same part, that is, whose origin and structure are similar, we call them *homologous* organs. Thus we may say that the antennae and claws of the crayfish are homologous to the swimmerets, or that our arm is homologous to the foreleg of a horse, even though the functions are so different. This word is the mate to *analogous* which meant similar in function. We might say that the gills of the crayfish and the lungs of man are analogous, because they both perform the function of respiration but we cannot say they are homologous, since the gills are developed from the legs, while the lungs are outgrowths of the throat.

Internal Structure. Internally, also, there is a considerable degree of specialization. The digestive system and its glands occupy a large part of the cephalo-thorax, there being three sets of teeth in the stomach, to complete the chewing of the food which was begun by the jaws. A well-developed circulatory system and a complicated heart mark an advance along this line. The excretory and reproductive organs are present and fairly developed. The nervous system, though similar, is much more specialized than in the worms. The senses of touch and smell, located in the antennae, are probably acute. The eyes are on movable stalks and are compound, each consisting of numerous lenses, but the sight is probably not keen. The ears are located at the base of the antennae but neither hearing nor taste seem to be especially developed.

While these sense organs do not seem very efficient, yet enormous advance can be seen when they are compared with the earthworm with no organs of special sense at all. The worm probably feels only touch and vibration sensations through the body wall, with a possibility of taste and heat or light sensations in the region



FIG. 60. Longitudinal section of the lobster showing the arrangement of the internal organs. From Calkins.

of the head. Since the degree in which an animal can get in touch with its environment marks the stage of its advancement, the crustacea far excel the worms in development.

Locomotion. This function is provided for by the swimmerets which carry the body slowly forward, by the tail flipper which drives it swiftly backward, and by the four pairs of walking legs which can travel in either direction and sideways as well. All are operated by powerful muscles, assisted by the exo-skeleton. You can see why the slang expression "to crayfish" means to back out of any agreement.

Protection. The crustacea's adaptations for protection are the exo-skeleton with its color and spines, the powerful jaws and claws for attack, speed for escape, fairly keen senses, and a nervous system to guide its actions.

Respiration. Respiration in protozoa was accomplished by contact of the cell with dissolved oxygen in the water; in the worm by contact of the body wall with oxygen in the air; osmosis was the method in both cases. In the crustacea we have organs called gills, specially developed for carrying on the exchange of oxygen and carbon dioxide. These gills are thin walled, to allow osmosis, feathery to expose much surface, provided with many blood vessels to receive oxygen and to liberate carbon dioxide, and also are arranged to insure a constant flow of fresh water over them. This last is brought about in part by the gill bailer, attached to the second maxilla and partly by the gills being attached to the appendages. These move in the water, with every motion of a leg or maxilliped. Finally, as the water passes under the carapace from behind toward the head, this flow is aided every time the animal swims backward. The gills are protected by the carapace, which extends over them and forms a chamber which will hold moisture for some time, thus keeping them alive when removed from the water. Notice the importance of the fact that oxygen is soluble in water; if it were not, the aquatic animals could not exist, since it is the oxygen dissolved from the air, and not the oxygen of the water (H_2O) itself which all water animals use.

Food-getting. The food of the crustacea is usually animal, either alive or dead, some even being cannibals, while others act as useful scavengers. A few of the smaller forms are peaceful vegetarians. Their swiftness, claws, mouth parts, color protection, and sense of touch and smell all are adaptations for food-getting and their large number shows how well able they are to cope with their surroundings.

Life History. The eggs, which often number thousands, are laid by the female, fertilized by sperms from the male as they are laid, and attached to the swimmerets where they are carried and protected by the mother for about ten months. The young after hatching, which occurs in summer, cling to the swimmerets for some time. When first hatched they are very small, not entirely like the adult in structure, and they remain at the surface of the water for the first stages. After moulting four or five times, they settle down on the bottom among the rocks, where they live on smaller crustaceans. During these early stages which occupy ten to fifteen days they are nearly defenceless and millions are destroyed by other aquatic animals for food. After reaching the bottom they are somewhat better protected though still destroyed in large numbers. This high mortality is the reason for the production of such large numbers of eggs. During their life at the bottom, moulting occurs at longer intervals until adult size is reached at the age of five years (in case of the lobster) after which they do not moult oftener than once in one or two years.

Moulting. This moulting, or shedding of the exo-skeleton is a direct result of having the hard parts outside. They cannot grow larger except by shedding their armor, and this is a point in which the internal skeleton of the higher animals is a very great advantage. With it, growth may be continuous. However, the exo-skeleton provides better protection. When ready to moult, the lime is partly absorbed from the skeleton; the carapace splits along the back, water is withdrawn from the tissues which makes them smaller and the animal literally humps itself out of its former skeleton, leaving behind the lining of its stomach and its teeth. Immediately water is absorbed and growth proceeds very rapidly.

The lime is replaced in the new and larger armor and Richard is himself again. Usually the later moults take place in hidden locations and with haste, as the animal is totally helpless and a prey to all sorts of enemies when growing its new suit. It is at this time that "soft shell crabs" are caught, which are merely the ordinary crab in the act of moulting.

Reproduction of Lost Parts. In moulting or in battle with enemies, it often happens that appendages are lost or injured, in which case the limb is voluntarily shed between its second and third segments. A double membrane prevents much loss of blood, and a whole new appendage is developed to replace the injured member. This accounts for the common sight of crayfish, etc., with one claw much smaller than its mate.

This reproduction of lost parts depends upon the degree of complexity of the part. The earthworm may be able to regrow the whole posterior of its body while a starfish can develop all its organs if one ray and its base be left. The hydra and corals normally reproduce by budding off new individuals and the protozoa, simplest of all, regularly reproduce the whole animal by division in two parts. On the other hand, higher forms, such as man, have tissues so highly specialized that we cannot even grow a new finger. The best we can do, is to develop scar tissue to fill a wound, or grow new hair, nails, skin, and (once only) teeth. This is one penalty for high specialization.

COLLATERAL READING

(Crayfish and Lobster)

N Y. State Forest, Fish and Game Report (1898), p. 290; *U. S. Fish Commission Report* (1898), p. 229; *Invertebrate Morphology*, McMurich, p. 377; *Advanced Text*, Claus and Sedgwick, p. 461; *Invertebrate Anatomy*, Huxley, pp. 265-293; *Advanced Text*, Parker and Haswell (Vol. I), pp. 498-514; *Advanced Text*, Packard, pp. 226-272; *Animal Forms*, Jordan and Kellogg, pp. 93-104; *Animal Studies*, Jordan, Kellogg and Heath, pp. 109-120; *Animal Activities*, French, pp. 101-114; *Elementary Text (Zoölogy)*, Kellogg, pp. 144-155; *Elementary Text (Zoölogy)*, Colton, pp. 61-86; *Elementary Text (Zoölogy)*, Linville and Kelly, pp. 125-156; *Elementary Text (Zoölogy)*, Morse, pp. 130-147; *Elementary Text (Zoölogy)*, Needham, pp. 111-129; *Elementary Text (Zoölogy)*, Daven-

TABULAR ARRANGEMENT OF CRAYFISH APPENDAGES

Segment Number		Appendage	Related organs, etc.	Functions
Head (5)	1	eye and stalk		circumspection
	2	antennules	ear sac	touch (hearing)
	3	antennae	green glands	" (excretion)
	4	mandibles	palpi and teeth	mastication
	5	1st maxilla	small appendage	"
Thorax (8)	2d	"	"gill bailer"	" (circulate water)
	6	1st maxilliped	reduced gill and flabellum	prehension
	7	2d		mastication
	8	"	gill — 1	" (breathing)
	9	3d	gill — 2	"
	10	chela	gill — 3	catching prey
	1st chelate foot		gill — 4	locomotion
	2d	"	gill — 5	"
	1st non-chelate foot		gill — 6	"
	2d	"	gill — 7 reduced	"
Abdomen (7)	14	1st swimmeret	according to sex	reproduction
	15	2d	typical — 3-lobed	swimming or egg attachment
	16	3d	"	"
	17	4th	"	"
	18	5th	"	"
	19	6th	enlarged to flipper	backward swimming
	20	7th	reduced to spine	"

port, pp. 120-152; *Economic Zoölogy*, Osborne, pp. 174-200; *Economic Zoölogy*, Kellogg and Doane, pp. 106-125; *Applied Biology*, Bigelow, pp. 358-376; *Life and Her Children*, Buckley, Chap. VIII; *Animal Life*, Thompson, p. 25; *Seashore Life*, Mayer, pp. 77-112; *Life in Ponds and Streams*, Furneaux, pp. 179-200; *Talks About Animals*, pp. 3-45; *The Crayfish: an Introduction to Zoölogy*, Huxley, entire; *Practical Zoölogy*, Davison, Chap. IX.

SUMMARY

Contrast, worms, having only simpler tissues and organs, no skeleton, inactive.

Crustacea, with high specialization, skeleton, active, aquatic.

Characteristics:

External skeleton adapted for protection.

Jointed appendages adapted for rapid motion.

High specialization adapted for division of labor.

Gills and connected organs adapted for aquatic life.

Crayfish (as type of crustacea).

External Structure:

Exo-skeleton, for protection and to act as levers for muscles.

Protective adaptations:

Hard, limy, color, spines,

Projection over gills and abdomen.

Carapace, rostrum.

Lever adaptations:

Hollow, strong, light,

Hinge joints in all directions.

Body regions, cephalo-thorax and abdomen.

Cephalo-thorax:

Includes head and thorax, 13 segments,

United for strength, rostrum for protection.

Carapace over anterior and gills.

Head appendages:

Sense organs.

Antennules, antennae, for feeling or smell.

Eyes, ear sacs, sense hairs.

Mouth parts.

Mandibles, one pair for chewing.

Maxillae, two pair aid in holding food.

Maxillipeds, three pair, catching and chewing food.

Thoracic appendages.

Maxillipeds, three pair, holding and chewing food.

Large claws, defence and food getting.

Clawed feet, two pair, locomotion, prehension.

Unclawed feet, two pair, locomotion.

(Gills on all above appendages.)

Abdominal appendages:

Swimmerets, five pair for swimming and egg attachment.

Tail fin, sixth and seventh pairs, backward motion.

Study of appendages shows

1. Modification of similar part, swimmeret, for different uses (Homology).
2. Adaptation for different functions (specialization).
3. Division of labor among homologous parts.

Homology, likeness in structure and origin, shows relationship.

Analogy, likeness in function, not necessarily in structure.

Adaptations of Crayfish for

1. Locomotion.

Swimming forward by means of swimmerets.

Swimming backward by means of tail fin.

Walking either forward, backward, or sidewise.

2. Protection.

External skeleton, color, spines, carapace, projecting sides, speed, claws.

3. Food-getting (what food?)

Claws, speed, mouth-parts, senses, color.

4. Respiration (cf. protozoa and worms).

Gills, adapted by being thin; for osmosis

Being well supplied with blood.

Being protected; large surface.

Water current provided by

Gill bailer.

Locomotion backward.

Leg motion in all directions.

5. Sensation.

Eyes, ears, feelers, hairs.

Life History:

1. Egg fertilized, attached to swimmeret (protection, aeration).
2. Hatch in summer, remain attached to mother.
3. Grow by moulting (reason).
4. Top swimmers when young, then on bottom.
5. Why so many eggs needed.

Moulting:

Reason (cf. internal skeleton).

Process: Absorption of lime from shell.

Carapace splits.

Water withdrawn from tissues, causing shrinkage.

Humps out of shell.

Re-absorption of water and rapid growth.

Hasty formation of new skeleton.

Lost Parts Reproduced:

What animals can reproduce lost parts?

Why not so much in higher forms? (Greater specialization.)

What tissues can man reproduce?

CHAPTER XXIII

INSECTA, A CLASS OF ARTHROPODS

Vocabulary

Trachea, a breathing tube, admitting air to the tissues. Plural: tracheae.

Chitin, a horn-like, elastic substance found in the external skeletons of insects and other arthropods, pronounced "kite-in."

Accessory, additional or assistant organs.

Palpus, feeler or sense organ attached to the mouth parts of insects, etc. Plural: palpi.

Spiracles, external openings of the tracheae, used in breathing.

Ganglion, a mass of nerve tissue. Plural: ganglia.

The Insects include that division of the Arthropods which have head, thorax, and abdomen separate, one pair of antennae, three pairs of legs, usually two pairs of wings, and which breathe by means of tubes called tracheae. This group includes more species than all the other living animals together, there being about 300,000 kinds known already. Experts regard this as not more than one-fifth of all in existence. Not only are there many kinds of insects, but each kind produces myriads of individuals like the locusts and mayflies, whose swarms darken the sky. Their struggle for existence is very severe and this results in manifold adaptations of structure.

High Specialization. Highly specialized mouth parts for different kinds of food, wonderful leg and wing development for swift locomotion, marvelous instincts and complicated internal structure are some of the lines along which insects have developed in order to survive among their countless competitors in the race of life. Some are adapted for aquatic life, some take refuge by burrowing, some live in colonies like bees and ants, others fight their battles alone; some have become swift in running, leaping, or flight, while others have fallen back on parasitic laziness.

Classification. We cannot study all, or even one, species thoroughly. However the accompanying table will show the names and representatives of a few of the sixteen different orders, and then we shall take up two or three types in greater detail.

<i>Order</i>	<i>Representative</i>
Orthoptera	grasshopper — cricket — locust
Pseudo-neuroptera	dragon-flies
Hemiptera	true bugs — lice — scale insects
Diptera	flies — mosquitoes — fleas, gnats
Coleoptera	beetles
Lepidoptera	moths — butterflies
Hymenoptera	bees — ants — wasps

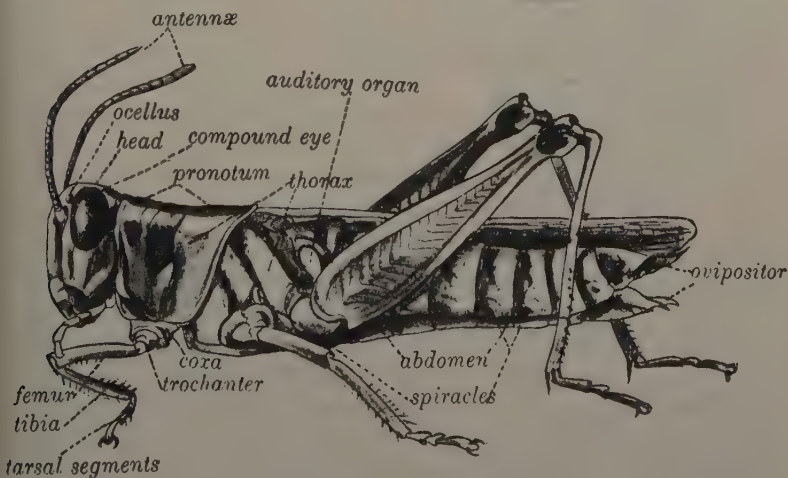


FIG. 61. Locust (enlarged) with external parts named. From Kellogg.

The Grasshopper. The grasshopper (which really is a locust) will be taken as a type of all the insects. It belongs to the order Orthoptera, which means "straight winged" and refers to the narrow folded wings, held straight along the body.

Exoskeleton. As in all Arthropods, the skeleton is external, but differs from the crayfish in that it contains no lime. It consists

entirely of a light, tough and horny substance called *chitin* which is usually protectively colored. The head, with its sense organs and mouth parts, the thorax with its legs and wings, and the abdomen, with its vent and reproductive organs, are all readily distinguished.

Head

Sense Organs. The antennae are the most anterior appendages and, as usual, are many jointed and devoted to the senses of touch and smell. There are two kinds of eyes, three simple

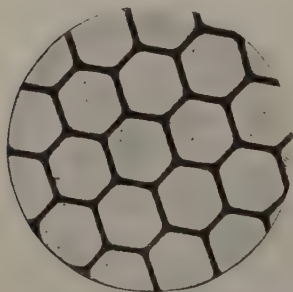


FIG. 62. Part of corneal cuticle, showing facets, of the compound eye of a horsefly, *Theriopterus* sp. (Photomicrograph by Mitchell; greatly magnified.) From Kellogg.

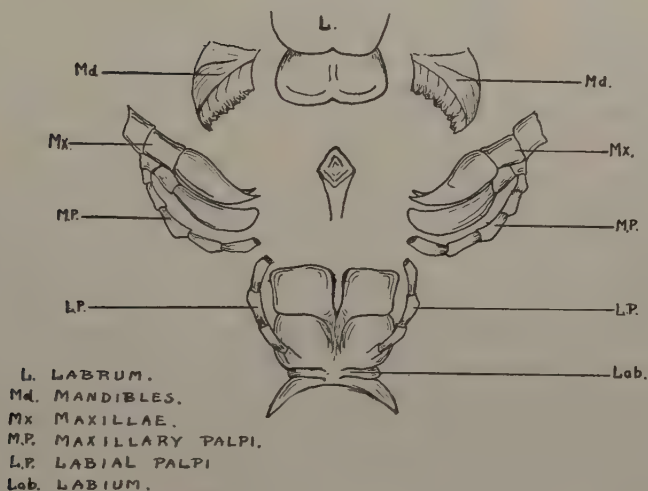
ones located respectively at the base of each antenna and on the ridge between them, and the large compound eyes projecting from the sides of the head and consisting of hundreds of six-sided lenses. The shape, location, and number of lenses in the eye seem to adapt the insect for sight in several directions at once, but the image formed cannot be very sharp.

Mouth Parts. The mouth parts of the grasshopper are fitted for biting and chewing hard foods and consist of labrum, mandibles, maxillae, and labium, named in order from the anterior. Though the mouth parts of insects are very greatly modified to suit all kinds of food, still these four sets of organs are always present, so we must become familiar with their names and appearance.

The labrum is the two-lobed upper lip which fits over the strong, toothed, horizontal jaws or mandibles. The pair of maxillae, or accessory jaws, are next behind the mandibles. They aid in cutting and holding food, and also have a sense organ, like a short antenna. This is called a palpus (plural: palpi). Posterior to the maxillae comes the labium or lower lip, a deeply two-lobed organ, also provided with palpi, which aids in holding food between the jaws.

GRASSHOPPER

= MOUTH PARTS =



LEAPING LEG

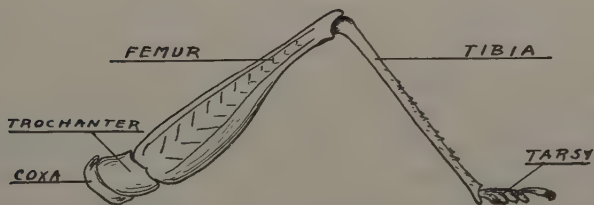


FIG. 63. Grasshopper.

Part I. Mouth Parts.

The upper lip or labrum is a thin scoop-shaped organ, which helps to hold food between the jaws.

The mandibles or jaws, are very thick at the edge, sharply toothed and operated by powerful muscles. They are dark brown in color and hard enough to gnaw dry wood.

The maxillae or accessory jaws are very complicated organs consisting of two sharp hook-shaped parts backed by a sort of hood. These help in holding food and perhaps in chewing it, too. Back of the hood are the palpi, whose

tips bear sense hairs, and perhaps enable the grasshopper to judge of the kind of food he may be eating.

The "tongue" or hypopharynx in the center, fits closely in the throat and seems to act as a sort of piston in helping to suck in the food particles.

The labium or lower lip, like the upper one, helps hold the food in place, but is much larger and has a pair of palpi, like those on the maxillae.

Such mouth parts are typically for biting and chewing and are similar to those found in many beetles, also.

Part II. The Leaping Leg.

The two short segments next the body are called the coxa and trochanter. Their function is to give freedom of motion to the base of the leg and to set it out a little from the side of the body so that it can push directly backward in jumping.

The thick part is the femur and contains some very powerful muscles, though the body muscles also help in jumping.

The tibia is the long thin part and is provided with backward projecting spines which prevent back sliding and aid in climbing through grass.

The foot consists of several tarsal joints with flexible pads and backward projecting spines which prevent slipping just like the spiked shoes of the human jumper. The claws at the end aid in this and also in climbing.

The knee and ankle joints move only in one plane, but the joints next the body can move sidewise also.

Thorax

The thorax consists of three segments, the pro-, meso- and meta-thorax. The prothorax is a large saddle-shaped segment to which the head is attached and bears the first pair of legs; the middle or mesothorax bears a pair of legs and the first pair of wings; while the last segment (metathorax) bears the leaping legs and the last pair of wings.

Legs. Each of these six legs consists of five parts or segments, connected by strong joints and adapted for locomotion by walking, while the posterior pair is also enormously developed for leaping. The feet (tarsi) are provided with spines, hooks, and pads to give firm grip when jumping or crawling. A joint near the body almost like a "ball and socket" permits sufficient freedom of motion.

Wings. The anterior (mesothoracic) wings are long, narrow, and rather stiff. They protect the more delicate under wings and act as planes in aiding flight and leaping. The posterior (metathoracic) wings are thin and membranous. They are supported

by many veins and, when not in use, are folded lengthwise, like a fan, beneath the narrower anterior wings.

Abdomen

The abdomen consists of ten movable segments, each composed of an upper and lower part, united by a membrane which allows it to expand and contract in the process of breathing. There are no jointed appendages as on the head and thorax, but eight of the segments have breathing pores (spiracles) on each side. The segment next to the thorax bears the ears which are large membrane-covered cavities on either side.

The extreme posterior segments in the female bear two pairs of hard and sharp-pointed organs called ovipositors (egg placers) whose function is to dig a hole in the ground in which the eggs are laid. The males have no such organs but the posterior of the abdomen is enlarged and rounded upward.

Active Life. The activity of insects is well known but little appreciated. They have the most enduring and powerful muscles of any animal, in proportion to their size. Think of the long swift flight of bees, often extending for miles, at enormous speed; think of the loads carried by ants and beetles; of the hard labor done by boring and burrowing insects, — then compare their size and weight with our own and see how fast we ought to fly or run, how far we should jump, or how much we should carry, if we had their muscular ability. Of course their enormous activity requires a great deal of energy which means that they must use a large amount of food, and this, in turn, implies a complete digestive apparatus. The digested food requires oxygen to oxidize it and liberate its energy and this requires a perfect system for breathing to supply the oxygen. To control such a powerful high-speed engine, a well-developed nervous system is also demanded.

The foregoing sounds like the "House that Jack Built" but is an outline of just what we find to be the case, not only in insects but in all higher forms. It is merely another instance of our order of study, "Structure, Function, Adaptation."

Internal Structure. The internal structure is very complex, some insects having over twice as many separate muscles as we have in our whole body. The digestive system is well developed, there being salivary glands, a crop, stomach, digestive glands, intestine, and rectum.

Excretion is provided for by a large number of thread-like tubes at the junction of stomach and intestine. Circulation, while not entirely inclosed in blood vessels, is controlled by a six-chambered heart on the dorsal (upper) side, from which the light-colored blood is forced toward the head and around throughout the tissues, in contact with the air tubes.

Respiration. The respiratory system is highly developed. It consists of an extensive network of air tubes called tracheae, there being six main tubes running lengthwise, from which branch air sacs and smaller tracheae reach every tissue in the body.

These tracheae open by means of the spiracles, which are tiny holes, protected from dust by hairs, found on the abdomen (8 pairs) and on the thorax (2 pairs). By alternate expansion and contraction of the segments at the rate of sixty-five per minute air is pumped in and out of these spiracles, and circulates through the tracheae, where, by osmosis, the oxygen from the air and carbon dioxide from the blood exchange places. A peculiar feature of the insect respiration is the fact that the air goes to the blood by means of the tracheae instead of the blood going to the air in capillaries as in our lungs. Another curious fact is that the veins of the wings are probably tracheae, adapted for the function of support rather than respiration.

Nervous System. The nervous system of insects reaches a higher degree of development than that of any invertebrate group and a comparison of the types studied can well be made at this time.

The *protozoan* cell received its impressions directly, it responded throughout, to heat, light, contact, and possibly other stimuli, but vaguely and without the aid of any nervous tissue.

In animals like the *hydra*, certain groups of cells seem more sensitive than others to external influences and also appear to control the activities of the animal. These are the simplest ex-

amples of a nervous system and might be regarded as unconnected nerve ganglia.

In the *worms* each segment has its nerve mass or ganglion, but all are connected by a double nerve fiber and each sends out many branches to various organs, which are thus controlled. Then, too, in the worms, there is a larger ganglion in the anterior end, above the mouth, which sends special nerves to the mouth parts and skin. Although there are no special organs of sensation, and the structure is very primitive, there is, nevertheless, an organ corresponding to a brain.

In the *crustacea*, the head ganglion, or brain, is located at the base of the rostrum. It is much larger than in worms and has branches extending to the eyes, ears, antennae, and mouth parts. This brain is connected with ganglia along the under side of the body but instead of having one for each segment, as in the worms, they are combined into eleven larger and more complicated nerve masses.

In the *insects* this combination of ganglia has gone farther still. Including the brain there are two ganglia in the head, three in the thorax, and five in the abdomen, and the brain and sense organs are much more specialized in function.

If we could study more kinds of animals we would observe this general tendency toward increasing the development of the head ganglia, of combining others and reducing their number, while increasing their ability, and the development of more efficient sense organs and greater motion control.

As soon as the simplest animal forms developed far enough to have one end always go forward (anterior) in locomotion, then that end, naturally, "ran into" contact with its environment. So, at the anterior end the sense organs could be most useful, which is the reason for this headward tendency in development.

In all animals the nervous system performs two general functions; it receives and appreciates impressions from without (sensation), and causes and controls motions from within (motor impulses). As the animals increase in complexity, the nervous system correspondingly develops. As the complexity increased, there was

greater need of one controlling region, so that all the body's numerous functions could operate in harmony and as a result the need of a brain developed. Its location, as explained above, was almost of necessity in the "head" or anterior end of the animal.

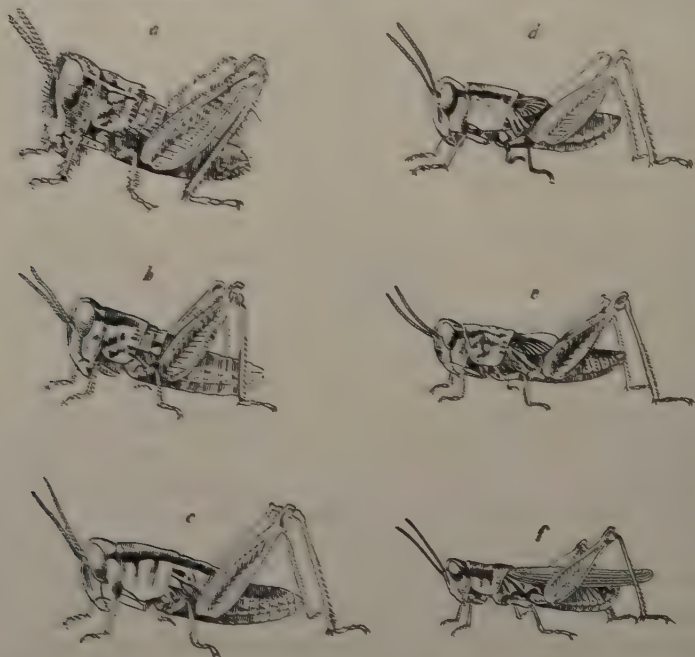


FIG. 64. Developing stages, after hatching, of a locust, *Melanoplus femur-rubrum*, a, just hatched, without wing-pads; b, after first moulting; c, after second moulting, showing beginning wing-pads; d, after third moulting; e, after fourth moulting; f, adult with fully developed wings. (After Emerton; younger stages enlarged; adult stage, natural size. From Kellogg.)

Life History. The eggs are fertilized internally, and are deposited in two masses, protected by a gum-like substance, in holes which the female digs in the earth with her ovipositor. From twenty to thirty eggs are thus deposited in the fall, and hatch the following spring. This illustrates a twofold advantage of egg reproduction, for, not only is the number of individuals increased, but they pass

the winter safely in the protected egg, while most of the adults are frozen to death. The young (nymph), though small, red, and wingless, still resembles the adult in most respects, but as is often the case with the young, the head is disproportionately large. As with all arthropods, they grow by moulting, usually five times, and at each step, develop in size and wings till they reach full growth. The moulting, which takes about half an hour, is followed by rapid growth and formation of a new exo-skeleton, the former one having split along the thorax to allow the exit of the growing insect. It emerges head first but very weak and limp, and often does not survive the process.

Metamorphosis. In many animals the development from egg to adult passes through more or less distinct stages instead of being a gradual increase in size. Such a life history is called a metamorphosis.

Among insects these stages may be several in number and the differences between them slight, as in the grasshopper, or there may be four definite and distinct stages, the egg, larva, pupa, and adult as found in the butterfly, for example. The former type is called an incomplete metamorphosis, the latter a complete metamorphosis.

Economic Importance. The members of the order to which the grasshopper belongs (orthoptera) are with one exception, all harmful to man. Their food is mostly cereal grains or crop plants, which they often destroy over wide areas. Locusts and grasshoppers have been a plague since ancient times. They are often referred to in Scripture and the second chapter of Joel contains a very vivid description of the destruction wrought by a swarm of locusts. The only useful relative is the mantis, which is carnivorous and eats other insects, many of which are harmful.

COLLATERAL READING

Life History of American Insects, Weed, pp. 67-81; *Insect Book*, Howard, pp. 334-340; *Insect Life*, Comstock, pp. 70-233; *Manual of Insects*, Comstock, pp. 104-118; *Guide to Study of Insects*, Packard, pp. 556-572; *Lessons in Zoölogy*, Needham, p. 48; *Textbook of Zoölogy*, Parker and Haswell, Vol. I, p. 584; *Textbook of Zoölogy*, Packard, p. 308; *Animal Forms*, Jordan and Kellogg, p. 117; *Animal Life*, Jordan and Kellogg,

p. 234; *Textbook of Zoölogy*, Linville and Kelly, pp. 11-14; *Elementary Zoölogy*, Kellogg, pp. 161-163; *Injurious Insects*, Treat, p. 269; *Injurious Insects*, Saunders, p. 157; *Introduction to Zoölogy*, Davenport, pp. 1-4; *Economic Zoölogy*, Smith, pp. 11-51, 79-100; *Economic Zoölogy*, Kellogg and Doane, pp. 14-25; *Descriptive Zoölogy*, Colton, Chap. I-III; *Practical Zoölogy*, Davison, Chap. I-VII; *Farm Bulletins*, Nos. 47, 59, 70, 80, 132, 209, 211, 247, 264, 284.

SUMMARY

Characteristics of Insects:

Separate head, thorax, and abdomen.
One pair antennae, three pair legs.
Usually two pair wings.
Breathe by means of tracheae.

High degree of specialization (adaptation) because of
Severe struggle for existence, because of
Very large number of species and individuals.

Specialized for various foods:

Vegetable foods	Grasshopper (biting)
Blood suckers	Mosquitoes
Sap suckers	Bugs and scale insects
Scavengers	Flies and beetles
Nectar	Bees and moths

Specialized for locomotion:

Crawling	Beetles, etc.
Flying	Bees, etc.
Jumping	Grasshopper
Swimming	Beetles and some bugs
Water surface	Striders
Burrowing	Ants, etc.

Specialized instincts:

(See references on Bees, Ants, Wasps, Termites).

General Structure:

1. Exo-skeleton, chitin, light, strong, and protective colored.
2. Regions:
 - Head for sense and food-getting organs.
 - Thorax for locomotion (respiration).
 - Abdomen for reproduction and breathing (ear).

Head:

Antennae, one pair, functions, cf. crayfish.
Eyes, simple, three, location.
compound, structure, why not on stalks?

Mouth-parts (biting).

Upper lip,	Labrum,	for holding food.
True jaws,	Mandibles,	for chewing.
Accessory jaws,	Maxillae,	to aid jaws (palpi).
Lower lip,	Labium,	to hold food (palpi).

Thorax.

Anterior thorax,	Prothorax,	Movable; legs attached.
Middle thorax,	Mesothorax,	Strong; wings and legs.
Posterior thorax,	Metathorax,	United to mesothorax wings and jumping legs.

Legs,

Functions: walking, clinging, leaping.

Structure.

Adaptations:

Strength of muscles.

Length of leverage.

Free backward movement.

Spines, pads, etc.

Point of attachment.

Wings.

First pair, planes and protection, concave, stiff, straight.

Second pair, thin, folded fan-wise, propellers.

Abdomen (structure).

Adaptations for respiration, spiracles, motion of segments.

Adaptations for reproduction, ovipositors.

Adaptations for hearing, ears.

Activity requires energy.

Energy requires food to supply it.

Food requires oxygen to release its energy.

Oxygen supply requires good breathing organs.

All this energy requires high nerve control.

Internal Structure.

Muscles, complex, strong, and very numerous.

Digestion, glands, crop, stomach, caeca, intestine, rectum.

Excretion, malpighian tubes.

Circulation, open system, dorsal, light color blood.

Respiration, spiracles, trachea, motion of abdomen.

Nervous system, high, senses well developed.

Development of nervous system:

Protozoa, direct to protoplasm, sense heat, light, contact.

Hydra, special nerve cells in *groups* (ganglia), motor control.

Worms, ganglia *connected*, beginning of *brain*.

Crustacea, fewer ganglia, cephalization, *sense organs*.

Insecta, very high brain ganglia, few others, great motor control, *instinct*.

General tendency of nervous development:

1. Fewer ganglia.
2. Increasing complexity (centralizing control).
3. Location in anterior (first contact with environment).

General functions of nervous system.

1. To receive impressions from without (sensation).
2. To control and originate motion (motor impulses).

Life History:

1. Egg, fertilized, buried in earth by ovipositors.
20-30 in two masses, in autumn.
Functions: to reproduce and to pass winter protected.
2. Nymph, like adult but small and wingless.
Growth by moults, development of wings.

Complete and incomplete metamorphosis compared.**Economic Importance.**

CHAPTER XXIV

INSECTA, CONTINUED

Vocabulary

Vestiges, remnants or traces of organs.

Metamorphosis, the series of changes in the life of an animal.

Credible, believable.

Communal life, life in colonies for mutual help.

Gorged, filled with food.

Bearing in mind the fact that all insects have, in general, the same organs as those found in the grasshopper, we shall now briefly study how they are developed in representatives of a few other insect orders.

LEPIDOPTERA

The *butterflies* and *moths* belong to the order lepidoptera (scale winged) and furnish a familiar type of quite a different group of insects.

Head. The antennae of butterflies are club shaped or knobbed at the tip while those of moths are usually feather like. The compound eyes are very large and rounded and the neck very flexible, but it is in the mouth parts that they differ most from the orthoptera, these being adapted for sucking nectar from flowers. The labrum and mandibles are reduced to mere vestiges while the maxillae are enormously lengthened and locked together to form the coiled proboscis or tongue which, when extended, may equal in length all the rest of the body and is always long enough to reach the nectar glands of the flowers they prefer. The labium is reduced in size, two feathery palpi being all that is left of it in most cases. Thus in this set of mouth parts, we have an example

of organs homologous to those of the grasshopper, but very differently adapted.

Thorax. The legs of the lepidoptera are small and weak, having the same general structure as in all insects. Obviously the butterfly neither walks nor jumps. It uses its legs only for clinging to its resting places and spends most of its time in the air. The wings are large and covered with colored scales from which the order gets its name. These scales help the few veins in giving

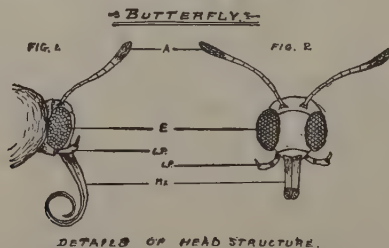


FIG. 65. Butterfly.

Fig. 1. Side view of head. — Note the club shaped antennæ with sense hairs at tip.

The enormous eyes curve out so far that vision is possible in all directions.

The small organs below the eyes are palpi from the labium, which are also sense organs.

The partly uncoiled "tongue" is composed of the two maxillæ, and has a roughened tip for opening the nectar glands of flowers. It is called the proboscis.

Fig. 2. Front view of head. — Same parts shown as mentioned above except that the proboscis has been cut through to show the two maxillæ, joined edge to edge with the tube between them for sucking nectar.

strength to the wing, and in some cases in color protection as well. The thorax and its muscles which move the wings are not very powerful, and the butterfly, though easily supported by its large wing spread, is not a swift flyer.

Abdomen. The abdomen resembles that of the grasshopper, but has fewer segments, and as in all insects is the least specialized body region.

Life History. The eggs of most lepidoptera are deposited on or near the plant which will be the food of the young. Some pass

the winter in this stage but usually eggs are deposited in the spring and partly develop that same season.

The egg does not hatch into a form at all resembling the adult, but instead, there emerges a tiny worm-like form called the *larva*, which differs entirely in structure, having no wings, nor compound eyes, but possessing several extra pairs of legs and biting mouth parts. In fact, these and other insect larvae are what we often call "worms," which they do somewhat resemble in shape. However, they are really one step in the development of an insect, and are vastly more complex than the true worms. The larval stage devotes its whole attention to eating, growing, and moulting, and after about five changes of clothing, it stops this gluttonous life in which it often does a great deal of harm, and goes into a resting stage called the *pupa*.

In butterflies, when the last moult occurs, a pupa case or *chrysalis* is formed which protects the insect during its long pause. The larva often seeks a protected spot or burrows in the earth before this change occurs. The moth larva, on the other hand, spins a wonderful case of silk, the *cocoon*, by which

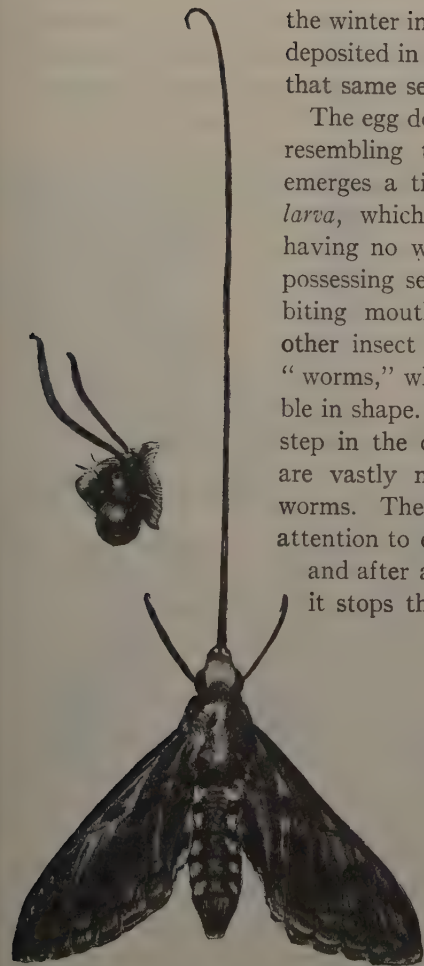


FIG. 66. Sphinx moth, showing proboscis; at left the proboscis is shown coiled up on the under side of the head, the normal position when not in use. Large figure, one-half natural size; small figure, natural size. From Kellogg.

it protects and attaches its pupa for its period of retirement.

This pupa stage in which the lepidoptera usually pass the winter, is not really a period of entire rest. Marvelous changes take place

which are not well understood, but this at least is known, the worm-like larva emerges totally changed both in internal and external structure, as the *adult* butterfly or moth.

Whereas the larva's function was to eat and grow, the adult eats only the nectar of the flowers and its life work is to produce or fertilize the eggs for the next generation.

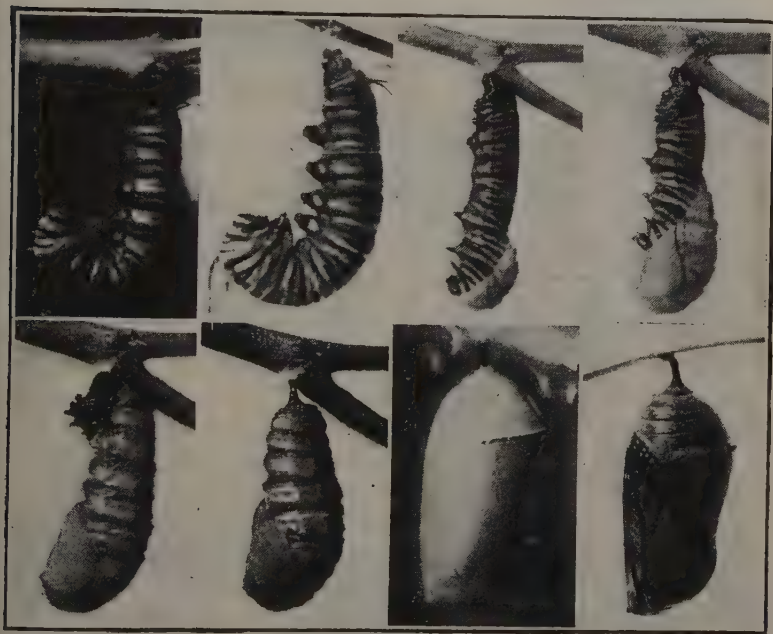
Such a life development, consisting of distinct stages, is called complete metamorphosis, as distinguished from a life history of gradual changes (like the grasshopper) which is called incomplete metamorphosis. Complete metamorphosis is not confined to the lepidoptera. The bees, beetles, and flies all pass through similar series of changes which can be tabulated as follows:



FIG. 67. Diagram of wings of monarch butterfly, *Anosia plexippus*, showing venation. *c*, costal vein; *s.c.*, subcostal vein; *r*, radial vein; *ca*, cubital vein; *a*, anal veins. In addition, most insects have a vein lying between the subcostal and radial veins, called the medial vein. Natural size. From Kellogg.

Egg	{ Deposited near source of food Period of increase in number
Larva	{ Period of eating and growth (usually harmful) Worm, grub, or maggot stage
Pupa	{ Period of quiet, internal transformation Usually pass winter in this stage Cocoon or chrysalis
Adult	— Reproductive stage

The larva of the lepidoptera is often very harmful as it feeds on man's crops, the multitude of so-called "worms" being only too familiar examples. The pupa stage of the silk moth furnishes us with silk from the threads of its cocoon. The adults aid in



Courtesy of the American Museum of Natural History.

FIG. 68. This caterpillar of the monarch butterfly is ready for the metamorphosis. It hatched in late summer and grew for two weeks. It stopped eating, chose a secure spot and spun a small thick carpet of silk. It walked over this until the hind feet were entangled in the silk, then it hung head downward, motionless. The skin now loosens, and after twenty-four hours splits over the head. At this stage the caterpillar, by muscular contraction works the skin off upward into a small shriveled mass; then during the few seconds longer that it still remains attached to the skin, it reaches out its slender end and with great effort and force pushes it up into the silk carpet. The whole process has taken but three or four minutes. Slowly the shape changes, the segments above contracting, the form rounding out; and behold an emerald-green chrysalis studded with golden spots! In two weeks the pattern of brown and orange wings begins to show through, finally the chrysalis skin splits over the head, and the butterfly crawls out.

the pollination of flowers, by reason of their thirst for nectar and their hairy bodies which carry the pollen.



FIG. 69. Metamorphosis, complete of monarch butterfly, *Anosia plexippus*. *a*, egg (greatly magnified); *b*, caterpillar or larva; *c*, chrysalis or pupa; *d*, adult or imago. After Jordan and Kellogg. Natural size. (From Kellogg.)

Moths and butterflies are often confused, but can be distinguished by the following comparison:

Butterfly	Moth
Day flier	Night flier
Chrysalis for pupa	Cocoon for pupa
Wings vertical when at rest	Wings held horizontal
Antennae knobbed	Antennae feathery
Abdomen slender	Abdomen stout

ORDER: HYMENOPTERA

The hymenoptera (membrane winged), which include the bees, ants, and wasps, represent the most highly specialized type of insect. In structure, instinct, and manner of life they far excel all their relatives. A complete account of the doings of some of the higher forms makes a common fairy tale seem credible by comparison. Huxley said that an ant's "brain" was the most

HONEY BEE.

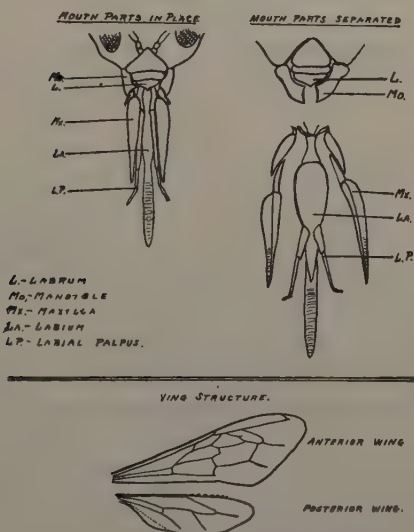


FIG. 70. Honey Bee — Mouth Parts, etc.

Figs. 1 and 2. Mouth parts. — The mouth parts as a whole are fitted for biting, cutting and lapping liquids.

The labrum is reduced to a small triangular organ, of slight importance except as a guide for the other parts.

The mandibles (Md.), are powerful, sharp-edged jaws with which wax or leaf material can be cut and worked.

The maxillæ (Mx.), are slender, pointed organs which can also be used for cutting and working in wax.

The labium is the most highly modified of the mouth parts (La.), and is

used for lapping up nectar from flowers. For this purpose it is long, slender and flexible, with roughened tip to hold more liquid. The labial palpi (L.P.) are attached at the side and are probably sense organs.

As a whole the bee mouth parts present a very high example of specialization, in which the usual six parts are developed to a condition little resembling the typical condition in the grasshopper.

Resulting from this, the bee can do several different operations with its mouth parts, while in most cases they would be fitted only for one, such as biting in the case of the grasshopper, or piercing in case of the mosquito.

Fig. 3. The Wings. — Attention is called to the relatively small size and fewness of veins in the bee wings. This is evidence of high specialization here, also, as they are perhaps the most efficient flying apparatus possessed by any insect, yet are comparatively small and light.

The few veins are placed in exactly those regions where strain is greatest, the wing muscles are powerful, and operate at a high rate of speed, which accounts for their small size.

The posterior pair bears a series of hooks which may attach it to the anterior pair, so that both act as one wing in flight, but fold back separately when at rest.

wonderful piece of protoplasm in the world, and this would apply almost equally to several other representatives.

Honey Bee. As an example of this order we shall study the honey bee, since it is a form with which all are familiar. The body regions are very distinct, the head being attached to the thorax by a flexible neck and the thorax to the abdomen by a slender waist. Each region is highly developed.

Head. The sensitive, elbowed antennae, the enormous compound eyes and three simple eyes are easily seen, but the mouth parts are very complicated and are really a set of tools by themselves. The *labrum* is small, but the *mandibles* are developed into efficient cutting and biting organs. They are used in manufacturing wax, leaves, etc., into cells. The *maxillae* are complicated organs adapted also for cutting and piercing as well as aiding in the work of the labium. The *labium* and its palpi form a very efficient "tongue" for lapping up the nectar upon which they live.

Thorax. The thorax is large, strong, and is provided with powerful muscles which operate the legs and wings.

The bees are notably swift and enduring flyers and their wings, while small, are exquisitely proportioned and operate at very high speed, producing the familiar hum. The anterior wing is much

the larger and the posterior wing may be attached to it, in flight, by tiny hooks. Honey bees often wear out their wings by constant use.

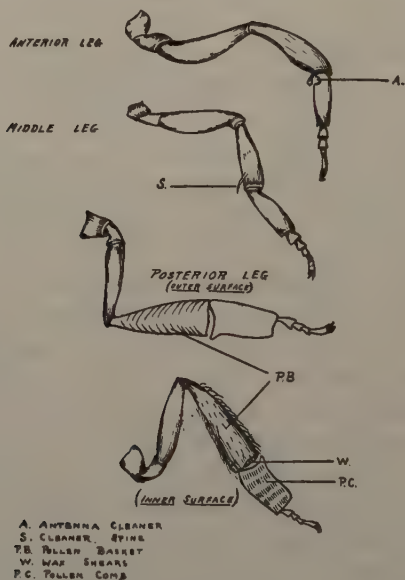
The three pairs of legs are each provided with special adaptations. On the anterior pair is found a notch and comb through which the antennae are drawn to clean them of pollen. The middle pair have a spine or spur which is used in transferring pollen back to the hind legs, which are most highly specialized of all. This pair has one segment bordered with strong hairs to form a basket for carrying pollen. The next segment has a series of combs for handling it, and between the two segments is a movable notch which is used as a shear for cutting and shaping the wax.

Abdomen. The abdomen consists of six segments, with ovipositor or sting at the posterior end. Between each segment are glands which secrete wax for comb making.

Life History. The life history of the honey bee is the best example of communal life and mutual help. Each member of the colony works for the good of all, and this unselfish habit has resulted in great success as a whole, as well as remarkable development for each individual. There are three forms of bees in any colony, the queen, drones, and workers.

The Queen. The queen is almost twice as large as the worker, with a long pointed abdomen, but with no pollen basket nor comb, her particular function being the production of eggs to continue the colony. She may produce as many as three thousand per day, which is twice her own weight. The queen develops from an ordinary egg, but the workers enlarge the wax cell in which it is to grow and feed the grublike larva with extra portions of nourishing food. This causes the development of a queen, or fertile female, instead of a worker, which is a female without the ability to lay eggs. After being thus fed for five days, the larva weaves a silken cocoon, changes to a pupa, and is sealed into her large waxen chamber by the workers. When the mature queen emerges from her cell, she seeks out other queen larvae in the colony and kills them, or if she finds another adult queen, they fight till one is killed. She never uses her sting except against another queen.

After a few days she takes a wedding flight in the air, where she mates with a drone, or male bee. Then the eggs are fertilized, and she returns to the hive and begins her life work of laying eggs. If the workers prevent her from destroying the other queens, she takes part of the colony and "swarms" out to seek a home elsewhere. A queen may live from three to ten years.



HONEY BEE
LEG ADAPTATIONS

FIG. 71. Honey Bee — Leg Adaptations.

Notice that in all the legs there are the same number of segments, but differently developed. This is an excellent example of division of labor or specialization among homologous parts.

The anterior leg has, at the first tarsal joint, a notch and a movable spine over it, so that the antennæ may be drawn through and cleaned of pollen after visits to the flowers. When you realize that the antennæ are the insect's most important sense organs, except possibly the eyes, this is seen to be an important special function.

The middle leg is only slightly modified, but has a strong spine which is used

in passing back the pollen from the other legs and depositing it in the pollen baskets.

The posterior leg, of which both surfaces are shown, is most highly specialized. Along the edges of the tibia are developed strong rows of hairs which form a pocket or basket, in which the pollen is carried.

The joint between the tibia and the first tarsal segment is shaped like a pair of shear jaws, and is used for wax working.

The first tarsal segment is provided with rows of stiff hairs which help to comb the pollen into the baskets, or from the opposite legs.

The rest of the tarsal segments are developed as usual, for clinging in locomotion, in the case of all three sets of legs.

In the bee, then, there are at least six different functions performed by the legs, for which they are provided with special structural adaptations.

Such high development is probably the result of the habit of communal life which permits greater division of labor than is possible where animals live alone or in pairs.

The Drones. The drone, while larger than the worker, is smaller than the queen and has a thick, broad body, enormous eyes, and very powerful wings. It is not provided with pollen baskets, sting, or wax pockets.

His tongue is not long enough to get nectar, so he has to be fed by the workers and his sole function is to fertilize the eggs of the queen. However, this easy life has its troubles for with the coming of autumn when honey runs low, the workers will no longer support the drones, but sting them to death, and their bodies may be found around the hives in September.

The Workers. The workers are by far the most numerous inhabitants of the hive; they are undeveloped females, smaller than drones with the ovipositor modified into the sting, and with all the adaptations of legs, wings, and mouth parts, which have been described.

With the exception of the process of reproduction, all the varied industries and products of the hive are their business and they perform, at different times, many different kinds of work as well as providing the three hive products — wax, honey, and propolis. In summer they literally work themselves to death in three to four weeks, but may live five to six months over winter.

Products of the Hive. *Wax* is a secretion from the abdominal segments of workers, which comes after they have first gorged

themselves with honey, and then have suspended themselves by the feet in a sort of curtain. As the wax is produced, it is removed by other workers, chewed to make it soft, and then carried to still others by whom it is built into comb.

This comb is a very wonderful structure, composed of six-sided cells in two layers, so arranged as to leave no waste space, and afford the greatest storage capacity with the use of the least material. Not only is it used for storage of honey, and "bee bread" (a food substance made from pollen and saliva) but also for the rearing of young bees, the eggs being placed one in a cell by the queen and sealed up by the workers, making what is called "brood comb."

Honey is made from the nectar of flowers which is taken into the crop of the bee, its cane sugar changed to the more easily digested grape sugar, and then emptied into the comb cells, where it is left to ripen and evaporate before being sealed up. Until the seventeenth century, people did not know how to make sugar, and depended upon honey entirely for this necessary food. At present the bee products in United States are worth \$22,000,000 per year.

The removal of honey by man does not harm the bees if about thirty pounds be left for their winter use, that being sufficient to feed the average colony of about 40,000 bees for an ordinary winter.

Propolis, or bee glue, is another important product of the hive. It is gathered from the sticky leaf buds of some plants. Bees will even use fresh varnish if they can get at it. It is used to make smooth the interior of the hive, to help attach the comb, to close up holes and cracks, and even to varnish the comb if it is left unused for a time; it is the brown substance which may be seen on section boxes in the stores.

Industries of the Colony. Not only do the workers prepare the wax, honey, and propolis, as needed, but they have other duties as well, which they also take turns in performing. Some attend and feed the queen or drones; some act as nurses to the hungry larvae, which they feed with partly digested food from their own stomachs; some clean the hive of dead bees or foreign matter; some

fan with their wings to ventilate the hive and, all the time, thousands of others are bringing in the nectar, pollen, and propolis as needed for use of the colony. Such a communal or colony life illustrates the highest development of division of labor found among the animals lower than man, and occurs among some ants and wasps as well as bees, though nowhere carried to a higher point than in the honey bee.

Larval Forms. The larval forms of many insects are so different from the adults that they have received separate names which sometimes confuse the relationship.

The larva of the	{	beetle	is called a	{	grub
		fly			maggot
		bee			grub
		mosquito			wiggler
		butterfly			caterpillar or "worm"
		moth			caterpillar or "worm"

We speak of "silk worms," or "apple worms," etc., when we really refer to larval forms of moths; "cabbage worms" and "currant worms" are larvae of butterflies.

"Wire worms" are beetle larvae; the "moth" that eats woollens is the larva and not the moth itself; the "carpet bug" or "buffalo bug" is the larva of a beetle.

COLLATERAL READING

Manual for the Study of Insects, Comstock, pp. 48-76, 104-118; *Insect Life*, Comstock, pp. 11-21; *Guide for the Study of Insects*, Packard; *Entomology for Beginners*, Packard, pp. 178-223; *Insecta*, Hyatt and Arms; *Elements of Zoölogy*, Davenport, pp. 11-89; *Animals and Man*, Kellogg, Chap. XV; *Textbook of Zoölogy*, Colton, pp. 1-53; *Lessons in Zoölogy*, Needham, pp. 36-104; *Practical Zoölogy*, Davison, pp. 30-125; *Comparative Zoölogy*, Kingsley, pp. 213-234; *Elementary Zoölogy*, Galloway, pp. 232-273; *First Book of Zoölogy*, Morse, pp. 49-108; *General Zoölogy*, Linville and Kelly, pp. 1-100; *General Zoölogy*, Herrick, pp. 153-195; *Animal Life*, Jordan, Kellogg and Heath, pp. 149-155; *Animal Studies*, Jordan, Kellogg and Heath, pp. 130-149; *Elementary Biology*, Peabody and Hunt, pp. 9-61; *Introduction to Biology*, Bigelow, pp. 279-286; *Applied Biology*, Bigelow, pp. 380-398; *Nature Study and Life*, Hodge, Chap.

V, X, pp. 181-294; *Handbook of Nature Study*, Comstock, pp. 308-451; *Life in Ponds and Streams*, Furneaux, pp. 202-345; *Life and Her Children*, Buckley, pp. 201-268; *Insect Friends and Foes*, Craigin, pp. 53-76; *Insect Life of Farm and Garden*, Sanderson, see index; *Insects Injurious to Fruits*, Saunders, see index; *Injurious and Useful Insects*, Miall, see index; *Insects and Insecticides*, Weed, see index; *Insects Injurious to Vegetation*, Chittenden, see index; *Insect Pests of Farm and Garden*, see index; *Insects Injurious to Trees*, N. Y. State Report; *Economic Entomology*, Smith, pp. 11-51, 79-100; *Economic Zoölogy*, Osborne, pp. 235-310; *Economic Zoölogy*, Kellogg and Doane, pp. 14-25, 125-182; *Life Histories of American Insects*, Weed, see index; *Insect Book*, Howard, pp. 332-346; *Butterfly Book*, Holland; *Moth Book*, Holland; *How to Know the Butterflies*, Comstock; *Cornell Leaflets* (bound volume), 1894-1904, pp. 135-140; *Cornell Leaflets*, pp. 226-261; *Cornell Leaflets*, pp. 529-557; *Cornell Leaflets*, pp. 213-223; *Cornell Leaflets*, 1915, pp. 153-190; *Cornell Leaflets*, 1916, pp. 122-152.

SUMMARY

Lepidoptera (scale winged) moths and butterflies.

1. Structure:

Head, antennae, knobbed or feather shaped.

Compound eyes.

Mouth parts (adapted for sucking nectar).

Labrum and mandibles reduced.

Maxillae form proboscis.

Labium reduced to palpi.

Thorax,

Legs small and weak.

Wings large, few veins, scaled, slow motion.

Abdomen,

Little specialized.

2. Life history (complete metamorphosis):

Egg laid on food plants.

Larva, caterpillar (eating stage), harmful.

Pupa, cocoon or chrysalis (quiet stage), silk.

Adult, moth or butterfly (reproductive stage) pollination.

Hymenoptera (membrane winged) bees, ants, and wasps.

1. Structure:

Head, antennae, short, elbowed.

Eyes very large.

Mouth parts (adapted for biting, lapping, and sucking).

Labrum, small, triangular.

Mandibles, sharp for biting.

Maxillae, long, sharp, for cutting wax, etc.

Labium, tongue-like, for lapping nectar.

Thorax, large and strong.

Wings small but powerful.

Legs, anterior with antenna cleaner.

middle with pollen spine.

posterior with pollen basket and wax shears.

Abdomen, six segments.

Ovipositor or sting.

Wax glands.

2. Life history (complete metamorphosis) communal life.

Egg, laid by queen in comb cells.

Larva, helpless grub, fed by workers.

Pupa, sealed in wax cell.

Adult, three forms as follows:

Queen, large, fertile female, produces eggs.

Drone, thick body, large eyes, fertilizes eggs.

Workers, smaller, sting in place of ovipositor.

3. Hive products:

Wax, secreted from abdominal segments of workers.

Honey, concentrated and partly digested nectar.

Propolis, glue made from plant gums. "Bee bread."

4. Division of labor (among workers).

Collection of nectar, pollen and gum.

Preparation of wax, honey, propolis, and bee bread.

Feeding queen, drones, and larvae.

Ventilating hives by fanning, cleaning hives.

Guarding hives from intruding insects and robber bees.

CHAPTER XXV

INSECTS AND DISEASE

FLIES AND MOSQUITOES

Vocabulary

Excrement, waste matter thrown off by animals from the intestine or kidneys.

Coöperation, working together for a single purpose.

Invariably, always, without exception.

Contract, to "take" a disease.

Another insect order which we shall take up very briefly is the diptera (two-winged) which includes the flies and mosquitoes. They are studied chiefly because of their relation to the carrying of disease germs. The diptera differ from all other insects by having but one pair of wings, the posterior pair being replaced by flat or knob shaped balancers. Their mouth parts are fitted for piercing, rasping, and sucking, and their metamorphosis is complete.

The Typhoid Fly. The common house fly (typhoid fly) has very highly developed mouth parts adapted for rasping and sucking, large eyes, and short fleshy antennae. Its wings, though but two in number, are well developed, and operated at high speed by the powerful muscles of the thorax; the posterior pair are replaced by flattened balancers. The six legs are well developed and the feet (tarsi) are provided with claws and sticky hairs which aid in locomotion. Unless these hair tips are very free from dust they will not stick well and the fly cannot walk readily on smooth surfaces, hence the care with which it cleans its feet by constantly rubbing them against each other and its body.

Life History. However, our principal concern is with the life history and habits of the fly rather than with its structure, since it is in this connection that it affects man's health.

The *eggs* are deposited in horse manure if it is to be found, or in other similar matter, about two hundred being laid by each female. They hatch in one day into the *larval* form which we call maggots, and in this stage do some good as scavengers. After eating and growing for about five or six days, the larvae pass into the *pupal* condition, inside the last larval skin, which thus takes the place of a cocoon. From this the adults emerge in about a week. The whole process occupies about two weeks, begins early in spring,



Courtesy of the American Museum of Natural History

FIG. 72. Common house (typhoid) fly.



American Museum of National History

FIG. 73. Eggs of the housefly.

and continues till cold weather. Supposing that half the eggs produced females and these reproduce at the same rate, calculate the number of flies that might be produced by one adult which had survived the winter, and the enormous number of flies in existence will be accounted for.

Danger from Flies. Flies have always been regarded as more or less of a nuisance, as they crawl over our food and our bodies, fall into milk and other liquids, and annoy man-

kind in various ways, but their real harm has only recently been realized.

They live in and feed upon manure and filth, then come and crawl over our food and faces, or wash themselves in the cream pitcher. When we realize that typhoid, cholera, and dysentery are intestinal diseases, that the germs are carried off by the excrement in which flies thrive, it is no wonder that they infect our food when



FIG. 74. Larvæ and pupæ of housefly, *Musca domestica*, in manure. Natural size. From Kellogg and Doane.

they crawl upon and share it with us. The fly is not only a filthy but a very harmful insect and one to be avoided and destroyed.

A fly eats its own weight of food every day. Its food is largely manure, sputum, and other filth, though it also samples our food at table. Disease germs pass through the fly's intestine unharmed and remain active in the familiar "fly specks" which are deposited at intervals of five minutes. Thus the fly carries filth and disease

both externally on its feet and body and internally by way of its food and excreta.

Our common flies transmit typhoid, cholera, summer complaint, dysentery, tuberculosis, and probably other diseases where the germs pass from the body in any form of excrement, pus, or sputum. The tsetse fly of Africa transmits the deadly "sleeping sickness." Thus it is seen that flies which we formerly regarded as an un-

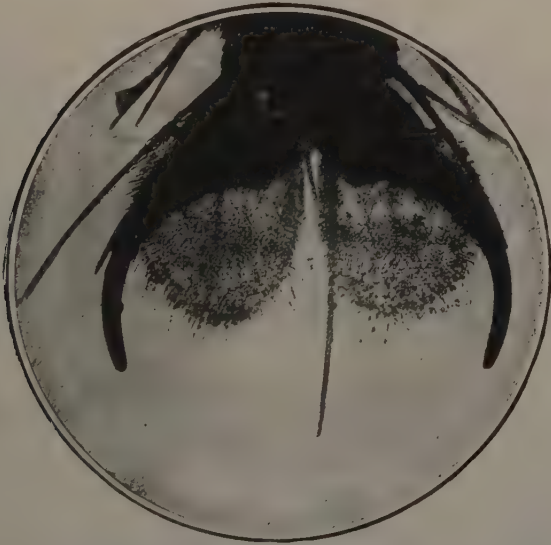


FIG. 75. Foot of housefly showing claws, hairs, pulvillæ and the minute clinging hairs on the pulvillæ. From Kellogg and Doane.

avoidable nuisance, have been proven to be responsible for the death of more people than all wild beasts and reptiles together, and that actually they are more dangerous to man than the tiger, grizzly, or rattlesnake.

Rate of Reproduction. In the face of its enormous rate of increase, "swatting" of individual flies is a losing battle as the following figures show. Supposing that reproduction was unchecked and that all offspring survive (which fortunately is not

always the case) then one fly would produce in the different generations of two weeks each as follows.

1st	200 (half females)
2nd (100 x 200)	20,000 (" ")
3d (10,000 x 200)	2,000,000
4th	200,000,000
5th	20,000,000,000
6th	<u>2,000,000,000,000</u>
	2,020,202,020,200 total in 12 weeks

or the perfectly unthinkable number of over two million millions in half the breeding season, which would be over 20,000 flies to be killed by each man, woman, or child in the United States — and this the progeny of one adult female which survived the winter.

Fly Control. Fortunately there are more efficient ways of destroying this dangerous pest. These are briefly tabulated below: government bulletins fully describing all methods may be had for the asking, and general coöperation has much reduced the pest in many cities. The following are the most efficient methods of control:

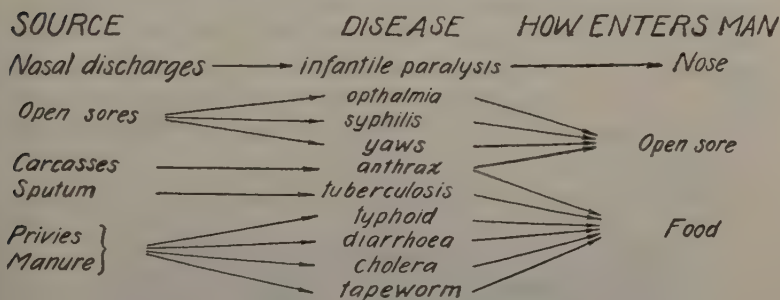
1. Horse manure and other filth can be removed, screened, or chemically treated to kill the larvae.
2. Garbage and sewage can be properly covered and removed.
3. Houses can be screened.
4. Food, especially in stores, can be protected.
5. Fly traps and wholesale poisons are helpful.

The Mosquito. The mosquito is another member of the diptera which demands mention because it, too, transmits serious diseases to man though it acts in a different way from the fly. The germs actually develop a part of their life history within the mosquito's body, while the fly merely carries its dangerous burden, mechanically.

Mouth Parts. In the mosquito, the labrum, tongue, mandibles, and maxillae are reduced to sharp, lance-like bristles, enclosed within the labium as a sheath, and are adapted for piercing and sucking. In order to dilute the blood, so that they can withdraw

it, they inject a little saliva, which causes the usual irritation and swelling of a mosquito bite.

Disease Transmission. This would be bad enough, but it has



SWAT THE FIRST FLY



MAY 1-1 Fly lays	120 eggs
MAY 10-60 Flies lay	7200 eggs
MAY 20-3600 Flies lay	423000 eggs
MAY 30-216000 Flies lay	25920000 eggs
JUNE 10-12960000 Flies lay	1555200000 eggs
JUNE 20-77000000 Flies lay	933120000000 eggs
JUNE 30-304665600000 Flies lay	5598720000000000 eggs
JULY 9-27993600000000 Flies lay	3259232000000000000 eggs
JULY 11-16796160000000000 Flies lay	20153920000000000000 eggs
JULY 29-100776960000000000 Flies lay	1209323520000000000000 eggs
AUGUST 8-6046617600000000000 Flies lay	725594112000000000000000 eggs

FIG. 76.

Upper.— Diagram showing the relation of flies to disease.

Lower.— Cartoon from newspaper showing rate of increase of the fly.
From Pearse.

been absolutely proven that if certain species of mosquitoes bite a person having either malaria or yellow fever, the protozoan which causes the disease, is taken up with the blood, develops in the mosquito's body and may be injected with the saliva into the

blood of a well person. Not only has this been shown, but by means of experiments in which several men sacrificed their lives, it is also proven that this is the *only* way in which these, and probably other diseases, are transmitted. Men tended yellow fever patients, slept in their beds, wore their clothes and though exposed in every way, did not contract the disease as long as screened from mosquitoes. Others who allowed themselves to be bitten by mosquitoes which had previously bitten yellow fever patients, invariably contracted the disease, which in some cases resulted in their death. From these sacrifices, methods of control have



FIG. 77. Mass of mosquito eggs.

developed which have saved thousands of lives in all parts of the world.

Life History. As with the fly, a knowledge of its life history enables man to contend with the mosquito, and these campaigns are much more successful than those against the fly. The eggs are laid in stagnant water; ponds, rain barrels, and even tin cans furnish ideal breeding places. They are deposited in tiny rafts, consisting of many eggs covered with a waterproof coating, and when they hatch the larvae emerge downwards into the water, and become the familiar "wrigglers" seen in rain barrels. Though living in water the mosquito larva breathes air, which it obtains through a tube, projecting from the posterior of its abdomen. It may often be seen with this tube at the surface and the body

hanging head downwards in the water. The pupa stage is also passed in the water and differs from most insect pupas in being an active "wiggler" as well as the larva. It differs from this larva in having a large head provided with two air tubes for breathing. The adult emerges from the floating pupa skin and is easily killed by any shower that wets its unexpanded wings, or any spray that may be thrown upon it.

Our commonest northern mosquito (*Culex*) probably does not

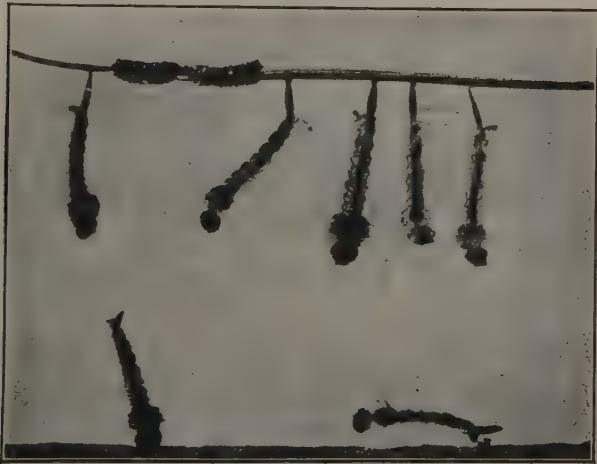


FIG. 78. Mosquito eggs and larvæ (*Theobaldia incidens*); two larvæ feeding on bottom, others at surface to breathe. From Doane.

transmit disease and may be distinguished from anopheles, which carries malaria, by the fact that the latter stands almost on its head when at rest, while *Culex* holds its body more nearly horizontal. Fortunately, *Stegomyia* which transmits yellow fever, is a tropical species of mosquito and does not usually invade the temperate regions.

Mosquito Control. This outline of the metamorphosis gives the key to the methods of attack which consist of:

1. Drainage of swamps, covering or removal of rain barrels, cisterns, cans, or any hollows where water may accumulate.
2. Spraying swamps and ponds with petroleum which covers the water with a film of oil so that neither larva or pupa can breathe, and also kills any adults which it strikes, though this oil treatment is injurious to plants and fishes in the water thus treated.



FIG. 79. Mosquito larvæ and pupæ, *T. incidens*, with their breathing-tube at the surface of the water. From Doane.

3. Fish and dragon flies are natural enemies of mosquitoes and should be encouraged.
4. Careful screening of houses and wearing of protective clothing especially in infected regions is a helpful precaution.
5. Persons suffering from malaria should avoid being bitten lest they thus infect others. Yellow fever cases are now quarantined in screened rooms for the same reason.

By such methods both malaria and yellow fever have been stamped out in many regions formerly very dangerous. The chief obstacle to the completion of the Panama Canal by the French was the awful death rate due to these diseases. Now, with proper sanitary measures, the canal zone has a lower death rate than New York City. Because of the modern knowledge of disease transmission and control as applied by Colonel W. C. Gorgas, the completed canal stands as a monument to American health science as well as to American engineering. The consequences of heroic experiment have been far reaching in other notable plague spots. Central America, West Indies, and the Philippines are now healthful regions. New Orleans, formerly scourged by epidemics of yellow fever, is now almost free from this dreadful malady.

A Biologic Victory. One of the most brilliant chapters in the history of the war against disease recounts the work of four American Army Surgeons in the conquest of yellow fever.

In 1900, Doctors Reed, Carrol, Lazear, and Agramonte were sent to Cuba to study this disease which had always been a scourge in the West Indian region and was now spreading among our soldiers. They suspected a certain kind of mosquito as the carrier, but could not test their theory on animals, as only human beings have yellow fever. So they decided to try it on themselves, and allowed mosquitoes, which had bitten yellow fever patients, to bite them and infect them with the deadly germs. Carrol was the first to be ill, but after a long and painful sickness, finally recovered. Lazear was the next to come down with the disease and he died. Still the experiments went on, despite the terrible risk, and there were many new volunteers. Two others were selected, a soldier, Kissenger, and a civilian, Moran. Both insisted that they receive no pay, as they willingly offered their lives for the benefit of humanity. Both men recovered after severe illness, but Kissinger was permanently disabled as the result of his heroism.

Based on the work of this gallant band of soldiers of science, they were able to prove that the mosquito was the *only* carrier of yellow fever, and to propose means for its control. An active campaign was begun at once and in 1901 only eighteen deaths

occurred in Havana and none at all in 1902. The terrible curse of the tropics was wiped out.

Major Reed writes "In my opinion this exhibition of moral courage has never been surpassed in the Army of the United States."

The history of medicine and sanitation is full of such examples of quiet heroism, where men have offered themselves to suffering



FIG. 80. A female mosquito, *T. incidens*; note the thread-like antennæ. From Doane.

and death far worse than is incurred in battle and without the excitement of war or the encouragement of popular applause.

The conquest of malaria was brought about in similar manner, by the careful research and courageous experiment of English and Italian doctors. As late as 1894 the Standard Dictionary of Medicine said that malaria was caused by "an earth-born poison generated in the soil" and, as its name signifies, was associated with bad air especially night air.

The malaria germ had been seen by a French surgeon in 1880, but not associated with mosquitoes at all, though in 1884 an American, A. F. A. King, had urged this as possible. In 1897 two English physicians, Manson and Ross, traced the germ of bird malaria to the mosquito and the following year two Italians, Grassi and Bignami, found the germ of human malaria in the body of mosquitoes.

By experiments similar to those described for yellow fever, it



FIG. 81. A male mosquito, *T. incidens*; note the feathery antennæ.
From Doane.

was proven possible to live in health in the worst swamps of the Roman Campagna, if protected from mosquitoes. To finally prove their action in malaria transmission, Doctor Manson's son and another volunteer were inoculated with malaria by mosquitoes brought from Italy. Both took the disease, but fortunately were cured. It is to such work as this that science owes her victories and to it we owe also our greater safety from disease.

SOME MEANS OF DISEASE TRANSMISSION

Disease	Transmitted by	Means of prevention
Malaria	Mosquito	Drainage and oiling of swamps Screening and isolation of patients
Yellow fever	Mosquito	As above
Typhoid fever	Flies	Destroy breeding places Kill breeding females in spring Screen food and waste As above
Tuberculosis	Flies	
Dysentery	Flies	
Spotted fever	Ticks	Destruction of insect pest
Cattle fever	Ticks	Cleanliness
Relapsing fevers	Lice	Cleanliness, destruction of pests
	Bedbugs	
Sleeping sickness	Tsetse fly	Protection against fly attack
The "Plague"	Fleas on rats and squirrels	Destruction of rodent hosts

COLLATERAL READING

Principles of Health Control, Walters, pp. 347-369; *Civic Biology*, Hunter, pp. 217-231; *Economic Zoology*, Kellogg and Doane, pp. 349-385; *General Zoology*, Linville and Kelly, pp. 284-287; *Town and City*, Jewett, pp. 228-241; *Primer of Sanitation*, Ritchie, pp. 145-150, 103-116; *Applied Biology*, Bigelow, pp. 282-286; *Mosquitoes or Man*, Boyce, pp. 204-210; *Protozoology*, Calkins, pp. 279-285; *Essentials of Biology*, Hunter, pp. 258-260; *The House Fly*, Howard, entire; *Civic Biology*, Hunter, pp. 217-226; *Lab. Problems in Civic Biology*, Hunter, pp. 149-157; *Sanitation Practically Applied*, Wood, pp. 420-444; *Community Hygiene*, Hutchinson, pp. 220-232; *Scientific Features of Modern Medicine*, Lee, pp. 79-85; *Rural School Leaflet* (Cornell), Vol. IX, pp. 184-186; *Bulletin No. 74 Mississippi Exp. Station*, entire; *Numerous other Government Bulletins*.

See also references in encyclopedia or any textbook index on,

Flies	Typhoid fever
Mosquitoes	Malaria
Fleas	Yellow fever
Protozoa	Bubonic plague

Etc., etc.

SUMMARY

Reason for study of diptera.**Characteristics of diptera.**

One pair of wings, balancers, complete metamorphosis.

Mouth parts for rasping and sucking (fly).

Mouth parts for piercing and sucking (mosquito).

Fly.

Mouth parts for rasping and sucking, large eyes.

Thick fleshy antennae, powerful wings, sticky feet, hairy.

Life History.

Egg, laid in manure or filth, 200, hatch in one day.

Larva, maggot, scavengers, period: 5-6 days.

Pupa, passed in last larva skin, period: 7 days.

Adult, develop in two weeks all summer (compute numbers).

Harm done by flies.

Annoyance to people and animals.

Transfer filth to food.

Transfer germs externally and internally.

Typhoid, cholera, dysentery, tuberculosis, sleeping sickness.

Methods of control or prevention.

Cover manure

Remove garbage

Use screens

Cover foods

Use traps

"Swat 'em"

Mosquito.**Structure.**

Mouth parts for piercing and sucking, saliva injected.

Mandibles, maxillae, labrum, and tongue inside labium.

Relation to disease.

Malaria and yellow fever.

How proven.

How transmitted.

Life History.

Egg, in rafts on the water.

Larva, wigglers, breathe head downwards.

Pupa, also active, breathe head upwards.

Adult, female bites animals, male harmless.

Control and prevention.

Drainage of swamps.

Spraying with oil.

Fish and dragon flies.

Screening houses.

Protecting those who are sick.

Kinds.

Culex, common northern mosquito, body horizontal.

Anopheles, malaria, body almost vertical.

Stegomyia, yellow fever, tropical.

CHAPTER XXVI

INTRODUCTION TO THE VERTEBRATES

Vocabulary

Specialization, development of parts for special function.

Survival, remaining alive.

Ultimate, furthest.

Vertebrates, animals having a back bone composed of vertebrae.

While it is certain that all living things are more or less related to each other, still they have developed along very different lines, and to very different extents.

Among animals, the *protozoa* seem to have carried the specialization of the *single cell* about to its limit, which, while assuring their survival, could not possibly raise them very high in the scale of development.

The *sponges* have obtained the utmost possible advantage from colonizing slightly specialized cells in unspecialized bodies; and have attained a considerable advance over the *protozoa*.

The *hydra* and its relations reached a much higher plane by development of *tissues* for special purposes and among them first appear the three-layered body wall from which the organs in higher animals are derived.

The *worms* mark a very diverse class but some of them have well-developed systems of *organs*, digestive, circulatory, nervous, etc., which had never appeared in previous forms.

Diverging from the worm type it seems as if nature had tried out several schemes of development, carrying each to a point where it could no longer be much improved.

The *molluscs* represent the ultimate advantage to be gained from a protective shell and rather high internal development,

coupled, in most cases, with an inactive life. This made for safety first, but limited increase in activity and intelligence.

The *arthropods*, especially the insect class, tried what could be done with an external protective skeleton, but one provided with joints, so that activity need not be sacrificed to safety. This has produced the winners in life's race, if numbers be the standard.

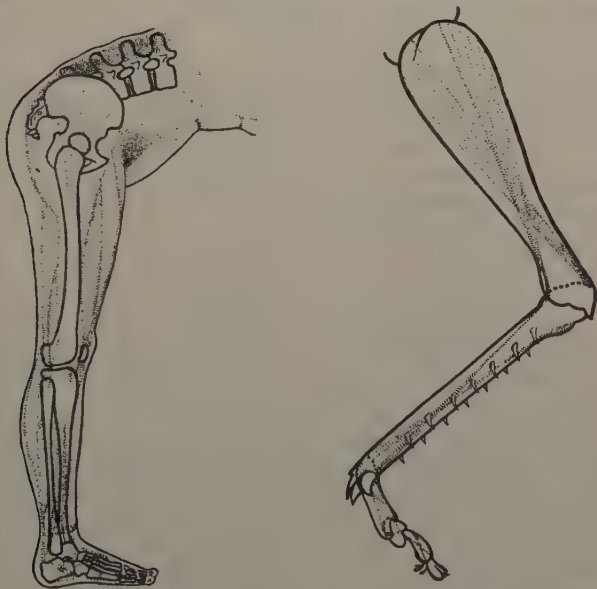


FIG. 82. Showing endo- and exo-skeletons.

The bones in a man's leg are surrounded by muscles; the skeleton of a grasshopper's leg consists of tubes with muscles inside. From Pearse.

But the external skeleton and the ventral nervous system imposed obstacles to large increase in size, on the one hand, and to a highly developed brain, on the other.

A third line of development, with the internal skeleton and the nervous system dorsal in the body, was attempted by the group of animals called the vertebrates. This permitted great increase in size both of body and brain, and while giving less protection,

this very fact necessitated an active and intelligent life to oppose or escape their enemies. The vertebrates thus have come to be the highest in the scale of animal development and include the following classes:

1. The Pisces (fishes).
2. The Amphibia (frogs, toads, salamanders).
3. The Reptilia (snakes, turtles, lizards).
4. The Aves (birds).
5. The Mammals (rat, cattle, cat, man, etc.).

The vertebrates include many very different animals, but they all agree in the following points, in which they also differ from all the other forms studied. These other forms are sometimes all classed together as the invertebrates.

All vertebrates have,

1. An internal skeleton of bone or cartilage.
2. A spinal column composed of vertebrae.
3. A dorsal nervous system.
4. Two body cavities: a dorsal one for the nervous system and a ventral one for the other organs.
5. Eyes, ears, and nostrils always on the head.
6. Jaws, not modified limbs; move up and down.
7. Eyelids and separate teeth are usually present.
8. The heart is ventral and blood is red.
9. Never more than two pairs of limbs.

The human body is a true vertebrate type as we can see by comparing its structure with the above points and we only hold our place in the race of life by our superior brain development. There is not one of the lower groups but has members which excel us in other respects.

Compare our swimming with the fish, our flight with the bird, or our speed with the deer and it will be seen that we are inferior in many respects to the different members of the animal kingdom. It is the development of our brain that has enabled us to retain the lead in the race of life. Superior intelligence compensates many times over for various physical disadvantages.

Here, as everywhere in Nature, we can see increase in complexity, permitting greater division of labor, and this in turn resulting in better adaptation and more perfect performance of function.

If we compare the protozoan to the man on the desert island, then the sponge would represent a condition where there were enough men (cells), so that one could do one thing and one, another. It would be like a small village where one man could make all the shoes, or do all the baking.

In the hydra we find groups of similar cells (tissues) performing

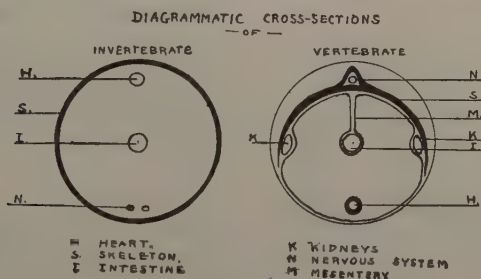


FIG. 83. Note differences in location of similar organs of vertebrate and invertebrate.

a single function. This would correspond to the case where the town had grown large enough so that many shoemakers or bakers were required and they each worked together, as in a factory.

Worms and higher forms, with their tissues grouped into organs, would correspond to larger cities where many kinds of factories were required to carry on the business of the still larger group of people.

COLLATERAL READING

Applied Biology, Bigelow, pp. 417-419; *Animal Studies*, Jordan, Kellogg and Heath, pp. 161-169; *Economic Zoölogy*, Kellogg and Doane, pp. 237-240; *Winners in Life's Race*, Buckley, pp. 1-19; *Animal Life*, Thompson, pp. 248-272; *Comparative Zoölogy*, Kingsley, pp. 127-156; *Zoölogy*, Shipley and MacBride, p. 306; *Elementary Zoölogy*, Davenport, pp. 289-297; *Elementary Zoölogy*, Galloway, pp. 274-280.

SUMMARY

Development of the branches of the Animal Kingdom.

Branch. Examples (in notes)

Line of development.

Protozoa

Specialized *single cells*.

Sponges

Groups of slightly specialized cells.

Larger size, colonial habit.

Hydra

Three-layered body wall, *tissues*.

Worms

Systems of *organs*, sense organs.

Molluscs

Protection, inactive, low intelligence.

Arthropods

Jointed exo-skeleton, active.

High developed senses and *instinct*.

Size and brain development limited.

Vertebrates

Internal skeleton.

No limit to *size of brain*.

Less protected but more intelligent.

Classes of vertebrates

Representatives

Pisces

Fishes,

Amphibia

Frogs, toads, salamanders.

Reptilia

Snakes, turtles, lizards.

Aves

Birds.

Mammals

Rat, cow, cat, man.

Characteristics of vertebrates

Sense organs on head.

Spinal column

Jaws not developed from limbs.

Internal skeleton

Dorsal nervous system.

Eyelids, separate teeth.

Two body cavities

Ventral heart, red blood.

Two pairs of limbs or fewer.

CHAPTER XXVII

FISHES

Vocabulary

Aquatic, pertaining to the water.

Cartilaginous, made of cartilage, a gristle-like tissue.

Nasal, pertaining to the nose.

Operculum, the covering over the gills in fishes.

Filaments, any thread-like organs.

Prehension, the function of grasping.

Visceral, pertaining to the viscera or abdominal organs.

Pectoral, pertaining to chest or shoulders.

Pelvic, pertaining to the hips.

Fishes are aquatic vertebrates, with either a cartilaginous or bony skeleton; they breathe by means of gills; are usually covered with scales; and have limbs in the form of fins.

External Structure. The body can be divided into three regions, the head, trunk, and tail. There is no narrowing to mark the neck, since the smoother outline is better fitted for passing through the water. The general outline of the body is spindle shaped, flattened more or less at the sides to aid in locomotion by displacing the water as easily as possible.

Scales. The whole body, except the head and fins, is covered with scales overlapping toward the rear, giving protection and at the same time allowing great freedom of motion. They are supplied with a slimy secretion which aids in locomotion and in escape from enemies. In some fish, such as the trout and catfish, the scales are minute or lacking, but in any case, the color of the skin corresponds to the fish's surroundings and is therefore a protection.

Head. The head is usually pointed, protected by plates instead of scales, and attached directly to the trunk. The lack of a neck is no disadvantage, as the fish can turn its whole body as quickly as most animals can turn their heads.

The *mouth* is usually at the extreme anterior since it is the only organ for food-getting or defense, and it is provided with numerous sharp teeth, arranged on three sets of jaw bones and slanting inward so that there is little chance for a victim to escape.

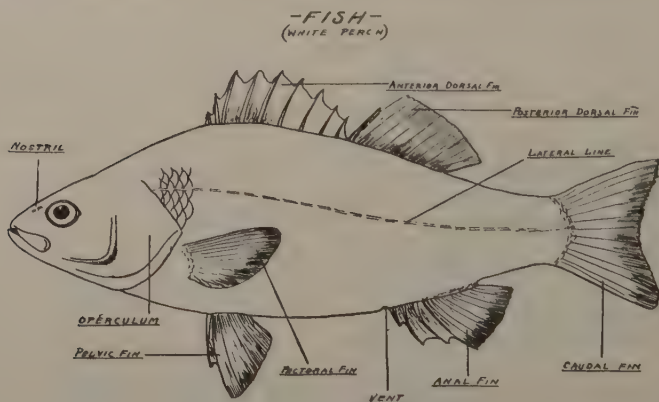


FIG. 84. Fish — External Features.

The *Fins* can be divided into those on the median line and those which are paired. The former are probably parts of a continuous fin which, in earlier forms, extended completely around the body, as in the eel or tadpole.

The dorsal fins can be erected and are armed with spines for protection. Smaller spines are also found in the anal and pelvic fins.

The caudal fin is the chief propelling organ and has flexible fin-rays for its support. All the fins in the median line aid in locomotion and steering.

The paired fins are homologous to the limbs of higher animals. The pelvic fins aid in supporting the fish when at rest on the bottom, and both pairs help in balancing and swimming.

The *Lateral Line* seems to consist of a series of gland-like sacs whose function is thought to be to provide a depth or pressure sense.

The *Nostrils* have two openings each, so that water can flow through them as the fish swims, bringing with it the particles which cause the sensation of smell. They do not connect with the throat and have nothing to do with breathing, as is the case of air breathers.

The *Scales* are arranged overlapping to the rear, to give all possible protection, and at the same time permit perfect freedom of motion, and offer no resistance to the water. A slippery secretion aids in locomotion and escape from enemies. Often their color is of advantage in escaping observation, either by enemies or prospective prey.

The *Operculum* is a strong covering which protects the very delicate gills from injury. It has a slight motion, so as to permit the water to pass out under-

neath it. The free ventral edge extends far forward under the head almost meeting in a narrow throat region, the isthmus.

All the above features are adaptations for aquatic life, and, together with other internal organs, have made the typical fish unusually well suited to its environment.

The general outline of most fish is about like the perch in having the flattened sides and tapering posterior, which make for speed. All fish have the bulk of their body composed of flexible muscle plates which permit powerful and free use of the caudal fin in locomotion.

There are two *nasal cavities* each with two nostrils, but they are used for smell only, since they do not connect with the throat and cannot be used in breathing.

The *eyes* are large, somewhat movable, and have no lids, but have a cornea, lens, retina, etc., somewhat similar to our own, and are entirely different from the compound eyes of the insects.

The *ears* are embedded in the skull and do not show externally; they probably function as balancing organs and are used to detect vibration, rather than sound, as fish have no sound-making apparatus and probably cannot "hear" in the sense that we do.

The Gills. At each side of the head is a crescent-shaped slit which marks the rear border of the gill cover or operculum. These slits almost meet on the ventral side, leaving only a narrow isthmus at the throat region, and thoroughly exposing the gills to the water. If we look inside the mouth we can see that the throat has five slits on each side, leaving four gill arches between them and if the operculum be lifted the outer sides of these gills can be seen.

Each gill consists of an arch of bone between the slits in the throat wall, to which are attached two rows of thin-walled thread-

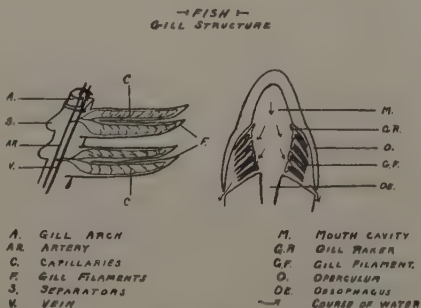


FIG. 85. Fish — structure of gill.

like appendages called the gill filaments. These filaments are richly provided with capillaries, so that the blood is brought in close contact with the water over a very large surface. This permits the exchange of oxygen (dissolved in water) and carbon dioxide by means of osmosis. The gill arches have finger-like projec-



Courtesy of the American Museum of Natural History

FIG. 86. Skeleton of European Perch, *Perca fluviatilis*, illustrating the bony framework of the higher fishes. After Cuvier.

The whole fish is adapted for thrusting rapidly forward through the water. The tapering head ends in a sharp prow extending from the nose to the neck. The brain-case is braced on all sides to receive the forward thrust of the many-jointed backbone, which is driven forward by the tail. The fins are spread upon bony sticks or rays, which are supported by bony pieces that are embedded in the flesh. Between the supporting pieces and the fin rays there are usually movable joints. The ventral fins are fastened beneath the pectoral fins, an arrangement which facilitates quick turning.

The propelling muscles and their bony supports are extended along the sides of the backbone and outside the ribs. The ribs enclose the stomach, intestines and other vital organs. These extract from the food the energy which is given out in muscular exertion. The region of the gills is covered by an elaborate system of jointed plates.

The mouth is guarded by bony jaws which are attached to the lower side of the skull.

tions on the side toward the throat called gill rakers, which prevent food or dirt from getting into the filaments and also keep the arches separate to allow free circulation of water.

The water is taken in at the mouth, which is then closed, forcing it through the gill slits over the filaments and out beneath the operculum; the forward motion of the fish aids in this process.

Here, as in all breathing organs, we find a large extent of surface, thin membranes, and rich blood supply, all adaptations for osmotic exchange, together with protective devices in the form of operculum and gill rakers, and provision for a free circulation of water.

Trunk. Extending along both sides of the body backward from the operculum is a row of pitted scales with sense organs beneath them, known as the lateral line, which probably aids the ears in feeling vibrations, and functions as a pressure organ to estimate the depth at which they swim. The fins are the most characteristic and noticeable appendages of the trunk and consist of a double membrane, supported by cartilaginous or spiny rays, and operated by powerful muscles. Their shape and number vary with the kind of fish, but there are always two pairs, the pectoral (anterior) and pelvic (posterior) fins, which are homologous with the arms and legs of other vertebrates. The other fins are all on the median (middle) line of the trunk, there being sometimes two dorsal fins; always a large tail (caudal) fin, and an anal fin just back of the vent. In general the fins are beautifully fitted for locomotion in the water, but they are differently used in this process, the caudal fin being the chief propelling and steering organ. The paired fins aid in locomotion and in balancing, and also support the body when resting on the bottom. The other median fins aid in steering and are often provided with sharp spines for defense as well.

The bulk of the fish's body consists of powerful muscles. The flexible backbone is made up of very numerous vertebrae, which, together, permit the fins to be utilized to the fullest extent and provide a system of aquatic locomotion, second to none in the world, aided as it is by the pointed, scale-covered, slippery body.

Internal Structure. Digestive System. The food of most fishes consists of other aquatic animals, though a few are vegetarians. It is grasped by the mouth, but the teeth serve only for prehension and not for chewing. On this account the gullet is large and short, the stomach provided with powerful digestive fluids and usually with finger-like outgrowths (caeca) to increase the digestive surface. As in most carnivorous animals, the intestine is rather short,

making only two loops, and opening into it is the duct from a well-developed liver between whose lobes the gall sac can be found.

Circulation. The fish has a heart consisting of two chambers, an auricle and a ventricle, located just posterior to the isthmus. So it is literally true that its "heart is in its throat." The blood leaves the heart by a large artery that branches to each of the gills, in whose filaments it is relieved of its carbon dioxide. Then laden with oxygen it flows into a dorsal artery with branches to

all the muscles and internal organs where it exchanges this oxygen for carbon dioxide. The blood which flows to the digestive organs receives the digested food-stuffs which they have prepared, and passes through the liver and so back to the auricle of the heart. Thus it hap-

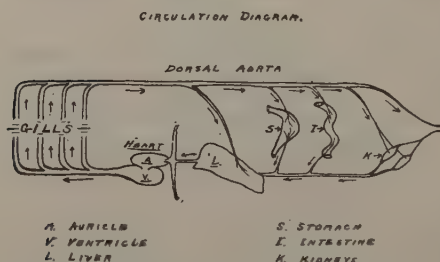


FIG. 87. Diagram of circulation in fish.

pens that the heart is always pumping blood that is rich in nutrients and carbon dioxide but poor in oxygen. The course of the blood stream is from the ventricle of the heart, to gills, to general circulation and digestive organs, to liver, and back to auricle of the heart again, though a part passes through the kidneys each time, where urea and other wastes are removed.

Nervous System. The central nervous system in all vertebrates is located in the dorsal body cavity, protected by outgrowths from the spinal column. This arrangement is entirely different from that found in the invertebrates, where the nervous system lies along the ventral side and is not separated from the other internal organs.

In the case of most fishes the nervous system consists of the spinal cord, extending the whole length of the body, protected by arches of bone attached to each vertebra. From it many nerves extend to the muscles and internal organs. At the anterior, the

cord enlarges to form a brain, entirely different in structure from the so-called brains of the lower forms, in that it has developed separate regions for different functions. The fish's brain consists of five principal parts. Beginning at the anterior, come the olfactory lobes from which the nerves of smell extend to the nostrils. Posterior to these, and considerably larger, are the two lobes of the cerebrum, which control the voluntary muscles of the animal. The largest parts of the brain are the two optic lobes connected directly with the eyes and concerned, of course, with the sense of sight. Behind them comes the cerebellum, and finally the enlarged end of the spinal cord, the medulla, both of which have to do with regulating muscular action and the work of the internal organs. The medulla is also a region from which branch many important nerves.

The brain as a whole, compared with other vertebrates, is not highly developed. The cerebrum, the center of voluntary control, is actually smaller than the optic lobes, and the whole brain does not fill the cranium or skull cavity, which is partly occupied by a protective liquid. It is only when compared with the invertebrate forms, that the real advance of the fish brain can be realized. In them there were no special parts for separate uses, no division of labor or specialization, and so a highly developed instinct was the best such a brain could achieve.

In the vertebrate, the development of specialized parts of the brain, though very primitive at first, paved the way for a cerebrum which would exceed all the other brain regions in bulk, and control, not only voluntary motion, but thought and reason, as well. So when studying the simple brain of the fish, do not forget that it contains the possibilities of great advance, and is to be the line along which the highest vertebrate development will be attained.

Air Bladder. Another organ, simple in the fish, but which has a great future before it, is the air bladder which is found in most species. This consists of a thin-walled elliptical sac, located in the dorsal part of the visceral cavity and sometimes connected with the throat by a tube. Its function is to assist the fish in maintaining a level in the water; by contraction of its walls the fish can sink, and by expansion, rise without other effort.

It develops in the embryo fish as an outgrowth from the throat, extending back and enlarging into the present form, and often losing all connection with the outer air. It is in precisely similar manner that the lungs of all higher forms push out from the throat, while retaining their connection with the mouth and performing an entirely different function. Yet they are regarded as of like origin and structure, so the lungs are homologous to the air bladder of fishes, but by no means analogous (or like in function).

In this connection it is interesting to note that in certain Aus-

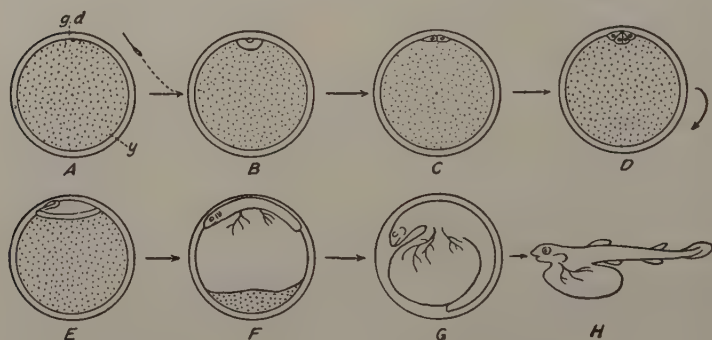


FIG. 88. Embryonic development of fish.

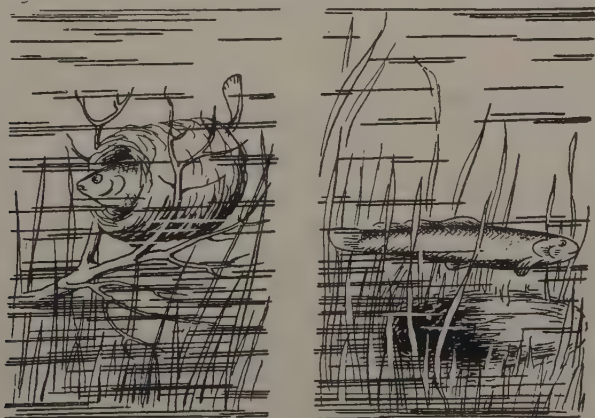
A, unfertilized egg; *gd*, germinal disc; *y*, yolk; B, zygote formed by union of ovum and spermatozoon; C, D, cleavage; E, young embryo showing neural groove at left; F, showing yolk nearly overgrown by the vascular membrane (blastoderm) growing out from embryo; G, embryo with "yolk sac"; H, young fish, just hatched, with yolk sac not yet absorbed. From Pearse.

tralian fishes the air bladder is actually used as a lung and the gills are poorly developed for breathing.

As the development of higher forms goes on, the simple air bladder becomes two lobed, its walls develop ridges, and finally many-celled chambers which enormously increase the interior surface. To the walls of these delicate cells a network of capillaries brings the blood, and devices are provided to pump air in and out. Thus from the air bladder of the fish, the lung of a bird or man may trace its origin.

Life History. The breeding habits of fish vary so greatly that it is difficult to make any general statements about their life history to which there will not be many exceptions.

The eggs vary in size from over an inch in skate, to the microscopic offspring of the herring. Their number may vary from five hundred in the trout to millions in cod, sturgeon, or flounder. The eggs are fertilized after being laid, by means of the spermatic liquid (milt) which the male sprays over them, sometimes stirring the eggs and milt together so that more shall be fertilized. There is little chance that all the eggs will be fertilized, since, as in the



Stickleback

Dogfish

FIG. 89. Fish nests. From Pearse.

plant, a sperm cell must reach each egg cell if it is to develop. Hence the large number of eggs is partly to make up for the small chance of fertilization. The eggs and young are prey to many other fish and similar enemies, while man destroys the adults for food, fertilizer, and fun. Out of enormous numbers of eggs, so few survive, in some cases, that artificial fish culture has to be utilized to prevent total destruction of certain species. In many cases both the fertilization and the care of young are left to chance, while in others, such as the bass, sunfish, trout, and catfish, a sort of nest is made on the stream bottom, where the eggs are guarded by the male, or may be covered with sand for protection.

As development proceeds the form of the embryo fish may be seen within the egg from which it soon emerges, retaining the yolk of the egg attached to the body, to be absorbed as nourishment until the tiny fish can shift for itself, and grow gradually to its normal size.

Life History of the Salmon. While no one fish can be taken as a type of all, the life history of the Pacific salmon is as well known as any and since it is so familiar an article of food, we shall take up its breeding habits somewhat in detail.

The adult salmon lives in the ocean all along the northern Pacific coasts. In spring or early summer both sexes migrate in enormous numbers up the Columbia and other rivers often to a distance of one thousand miles. It is during these "runs" that the canners make their annual catches by means of barriers or machines which scoop up the passing fish.

This migration may be for the purpose of finding greater safety, cooler water, or better food, or it may be a relic of the time when they may have been entirely fresh-water fish. At all events they begin in March to make their last journey. Slowly at first and later many miles per day they work their way against the current to the spawning beds far from the sea.

Here, in water not warmer than 54 degrees, each female deposits about 3500 eggs. The male spreads over them the "milt" or spermatic fluid at large in the water. It is much like wind pollination in flowers and many eggs are not reached by the sperms, hence do not develop.

The males are brilliantly colored at the breeding season but both sexes soon lose their beauty and strength, partly in fighting other fish and partly by injuries from the stones in the spawning beds.

The eggs are deposited on fine gravel and the process extends over several days after which the strength of the parents seems to be exhausted and both die.

After from thirty to forty days the eggs hatch, but as usual with fish, the yolk remains attached until all is absorbed in growth and the fry, as they are called, can shift for themselves.

Although many young salmon fall prey to other fish the majority find their way back to the ocean where they reach adult life, and, if they escape the canner's machines, live to repeat the self-sacrifice of their parents.

Adaptations. The study of the fish reveals an animal, first of all adapted for aquatic life, and nearly all features of its structure and habits tend to this result, as the following summary will show.

SUMMARY OF ADAPTATIONS

For Locomotion in Water.

1. Shape of body, slimy secretion.
2. Scales, fins.
3. Flexible spinal column and powerful muscles.

For Life in Water (see above, also).

1. Gills for respiration.
2. Air bladder, to regulate depth.
3. Lateral line to determine pressure.
4. Structure of eye, spherical lens.

For Protection.

1. Color, dark above, light below.
2. Scales, spines, teeth.
3. Speed, to escape enemies.

For Food Getting.

1. Location and size of mouth.
2. Shape and location of teeth.
3. Wide gullet and powerful digestion.
4. Speed.

COLLATERAL READING

General description and structure: *American Food and Game Fishes*, Jordan, pp. 364-367; *Fishes*, Chap. XXXIII, Jordan, p. 508; *Fishes*, Chap. X (adaptations), Jordan, pp. 51-78; *Familiar Fish*, McCarthy, Chap. 7; *American Natural History*, Hornaday, pp. 380-387; *Life in Ponds and Streams*, Furneaux, p. 353; *General Zoölogy*, Linville and

Kelley, p. 305; *Elementary Zoölogy*, Packard, pp. 142-175; *Animal Structures*, French, pp. 169-178; *Winners in Life's Race*, Buckley, pp. 20-42; *Economic Zoölogy*, Osborne, pp. 338-355; *Elementary Lessons in Zoölogy*, Needham, pp. 161-378; *Practical Zoölogy*, Davidson, pp. 185-199; *Comparative Zoölogy*, Kingsley, pp. 21-39; *Elementary Zoölogy*, Galloway, pp. 281-295; *Elements of Biology*, Hunter, pp. 271-278; *Applied Biology*, Bigelow, pp. 419-424; *Elementary Biology*, Peabody and Hunt, pp. 120-137; *Forms of Animal Life*, Rolleston, pp. 83-102.

Advanced works on structure: *Advanced Zoölogy*, Packard, pp. 411-460; *Textbook of Zoölogy*, Claus and Sedgwick, pp. 120-150; *Forms of Animal Life*, Rolleston, pp. 83-98; *Anatomy of the Vertebrates*, Huxley, pp. 59-65.

Classification and kinds of fish: *American Food and Game Fish*, Jordan (key), pp. 29-34; *Elements of Zoölogy*, Davenport, pp. 298-324; *Fresh Water Aquarium*, Eggeling, pp. 107-216; *Pet Book*, Comstock, pp. 226-245; *Handbook of Natural History*, Comstock, pp. 149-180; *Nature Study Leaflets* (bound), Cornell, pp. 157-166; *Winners in Life's Race*, Buckley, pp. 43-69.

Economic Value and Life History: *Fishes* (life history), Jordan, pp. 1-24; *Fishes* (as food), Jordan, pp. 129-148; *Familiar Fish* (propagation), McCarthy, Chap. 2; *American Natural History*, Hornaday, pp. 375-377; *Practical Biology*, Smallwood, pp. 103-112; *U. S. Fish Commission Report*, 1897; *Economic Zoölogy* (good), Kellogg and Doane, Chap. 21; *Elementary Biology*, Peabody and Hunt, pp. 137-150; *Talks About Animals*, pp. 7-35; *Animal Life*, Thompson, pp. 109-110, 253-256.

SUMMARY

Characteristics: bony skeleton, gills, scales, fins.

External Structure.

Shape, spindle outline for easy swimming.

Scales, for protection and ease of motion (cf. crayfish).

Head.

Mouth and teeth for prehension and defence.

Nasal cavities for smell, not breathing.

Eyes, with lens, cornea, etc., but no lids (cf. crayfish).

Ears, internal, detect vibration or balance.

Gills.

Gill openings, two at sides of head.

Operculum, cover over gills.

Gill arches, four, bony, hook shaped, support the

Filaments, numerous, much surface, thin, capillaries.

Gill rakers, clean and spread arches.

Trunk.

Lateral line, for depth sense.

Fins, a double membrane supported by rays.

Paired, pelvic, posterior, for locomotion and balance.

pectoral, anterior, for locomotion and balance.

Median, caudal, locomotion, and steering (tail).
dorsal (back) steering.
anal (vent) steering.

Body very muscular.

Internal Structure.

Digestive system.

Teeth for prehension, not chewing.

Stomach, with caeca, powerful fluids.

Intestine short and large, liver large.

Circulation.

Heart two chambered, anterior, ventral.

Blood flows to gills, to body, to heart, to gills, etc.

Nervous system.

Brain, separate parts for different functions (result).

Spinal cord, dorsal, protected by vertebrae.

Air Bladder.

Outgrowth from throat.

Function: to regulate depth.

Homologue of lung.

Life history.

Eggs small and numerous. (Why?)

Externally fertilized.

Slight parental care, many enemies.

Embryo retains yolk sac for food.

Grows gradually, not by stages. (Why?)

Life history of the salmon.

Adaptations.

See summary in text.

CHAPTER XXVIII

THE AMPHIBIA

THE FROG AND ITS RELATIVES

Vocabulary

Transition, period of change.

Vegetarian, using vegetable food.

Carnivorous, using animal food.

Constitute, to make up or compose.

Pulmonary, pertaining to the lungs.

Aerated, supplied with air.

Viscera, all the internal body organs.

Particular interest attaches to this group because of the fact that, in their life history, we can see the steps in development between the fishlike animals adapted solely for aquatic life and the land animals which cannot live under water.

In this transition from water to land forms, many strange combinations of gills and lungs, fins and legs, have occurred, gills being found on animals with legs, and fins sometimes accompanied by lungs. All together this is a very good object lesson in the development and adaptations of animal forms.

The name amphibia, meaning "having two lives," refers to the fact, that they usually are aquatic, fishlike animals when young, and abandon that manner of life for the land when they become adults. This series of changes is called a metamorphosis, just as was the life history of some insects.

Characteristics. The characteristics of the group may be summarized as follows, though there are some exceptions:

1. They undergo a metamorphosis.
2. Eggs are directly fertilized as laid.
3. Usually they are covered by a smooth skin.

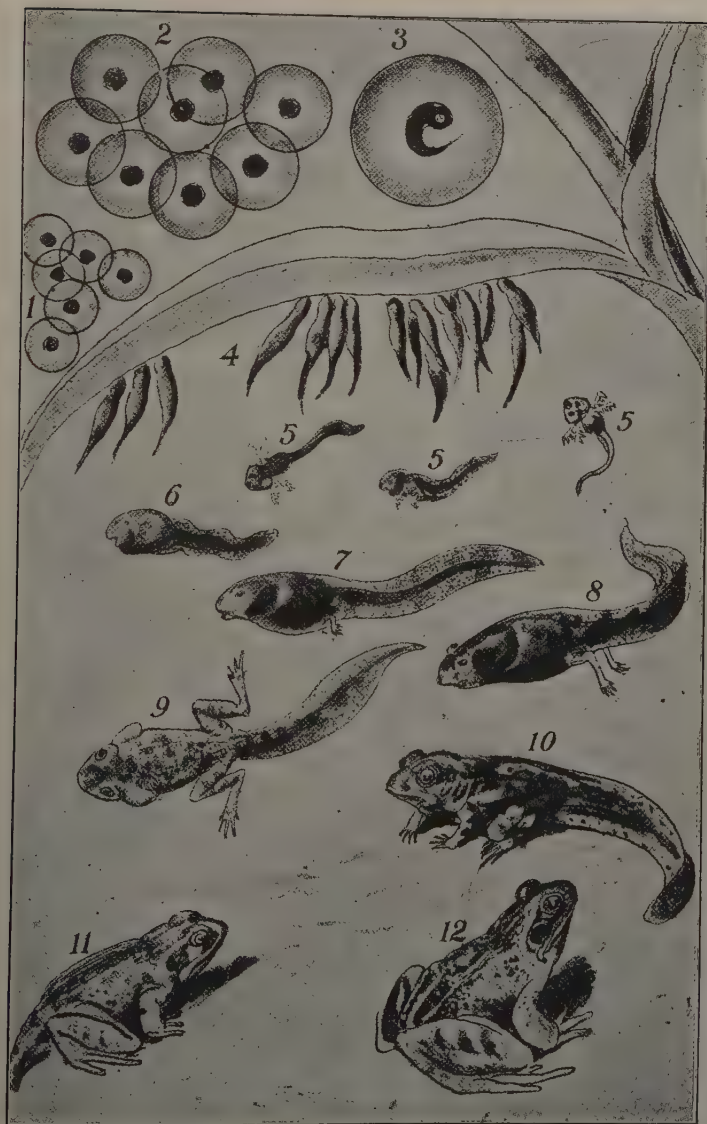


FIG. 90. Development of Frog.

Courtesy of D. Appleton & Company.

1, 2, 3, eggs; 4, young immediately after hatching; 5, tadpole with external gills; 6, 7, 8, 9, 10 and 11, further stages of development; 12, frog. (From Baskett and Ditmars' *Story of the Amphibians and Reptiles*.)

4. Larval forms are vegetarian; adults, carnivorous.
5. The heart is three chambered, and circulation well developed.
6. The brain, especially the cerebrum, better developed than in fish.

Among the representatives of this curious group, are several common animals. Frogs, toads, tree-toads, newts and salamanders are all familiar both by sight and sound.

The Frog. The frog will be taken as a type not only because common and convenient, but also because of the resemblance of its structure to that of the human being.

In the work with the frog, it is particularly desirable to compare its structure and development with that of the fish, whenever possible, noting those points in which it is more highly developed and the differences which its land life has made necessary in its structure.

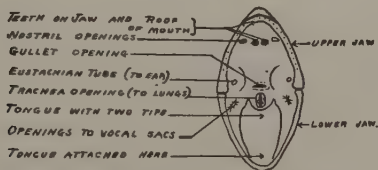
External Features. The frog's body is short, broad, and angular, evidently not as well adapted for submarine locomotion as the fish, nor has it achieved the graceful form of a highly specialized land animal. The covering is a loose skin, colored to resemble its surroundings, and provided with no scales nor hairs, but supplied beneath with many blood capillaries. It is evident that the skin is not for defense like the scaly armor of the fish but attains somewhat the same end by its protective coloration. Its thinness and rich blood supply permit a certain amount of respiration to take place through it. Many amphibians absorb water through the skin instead of by drinking. Some secrete a slimy mucus which assists in locomotion and escape from enemies. The head is broad, flat, and attached directly to the body. The nostrils are located near the anterior and connect directly with the mouth cavity, thus permitting them to be used for respiration. They can be closed by a valve-like flap when under water.

Head Structures. The Mouth. The mouth is enormous and extends literally from ear to ear. This is a very necessary adaptation for food-getting as the insects which constitute its principal diet have to be snapped up in this veritable trap. Another striking adaptation for the same purpose is the arrangement of the

tongue. This is attached at the *front* of the lower jaw, is very muscular, and has two sticky fingerlike projections at its tip. This peculiar tongue can be flipped out of the mouth so quickly

FROG

MOUTH STRUCTURE.—



ACTION OF FROG'S TONGUE

PROTECTIVE POSITION
IN WATER

FIG. 91. Frog. External Features.

Fig. 1. Mouth Structure.—The mouth is shown as if opened quite flat. There are no teeth on the lower jaw, as they would interfere with the tongue when extended as in Fig. 2. The teeth on the roof of the mouth are just where they will catch any insect which has been flipped into the mouth by the tips of the tongue.

The openings into the vocal sacs enable the frog to inflate his throat and, with these hollows as a sounding board, make such loud calls in the mating season.

Notice that the food has to pass *over* the trachea to reach the gullet, so the former is protected by a sort of lip-like valve.

The curved enlargements by the eustachian tubes are caused by the downward projection of the eyeballs.

Figs. 2, 3, and 4, show stages in the operation of the frog's tongue, in catching insects.

The tip is two lobed and sticky, the mouth enormous in width, and the

speed of the tongue is so great as almost to elude the sight, so it all makes a very efficient food-getting device.

Usually the frog jumps at the same time it extends its tongue, thus increasing its range very greatly.

Toads also have the same adaptation, and some salamanders are even better provided.

Fig. 5 shows the position of rest in the water, with the prominent eyes and anteriorly placed nostrils, just above the surface. In this position, either at rest on the bottom, or afloat with hind legs extended, the frog is almost invisible and thus escapes its enemies.

Note the inturned front feet, mere props and the hind legs, folded ready to swim or leap on the instant.

that the eye cannot see the motion; the insect sticks to it and is instantly thrown back within the capacious jaws, just where a set of teeth on the roof of the mouth will hold and crush it. There are no teeth on the lower jaw, as they would interfere when the tongue was thrown out over them. Those on the upper jaw are small, and in toads both sets are lacking entirely, as the real organ of prehension in either case is the remarkable tongue.

As we look inside the frog's mouth the nostril openings can be seen near the anterior of the upper jaw; the tongue folded back occupies the floor of the lower jaw; farther back at the sides are the openings of the eustachian tubes from the ears; and at the extreme rear, in the middle, can be found the wide gullet and slit-like opening of the breathing tube or trachea. The walls of the throat are loose and can be greatly expanded with air when the frog is calling, thus acting as resonating chambers. This gives great volume to the sound for which all frogs are noted.

Other Organs. The *eye* of the frog is one of the most beautiful in all the animal kingdom, having the black pupil surrounded by a handsome bronze colored iris of large size. It projects conspicuously from the top of the head, but can be withdrawn, level with the skull. It is protected by lids and an extra covering, the nictitating membrane, which can be raised from below and probably protects the eye when under water.

The location of the *nostrils* at the very tip of the head, and the high projection of the eyes enable the frog both to see and breathe while the rest of the body is covered by water. When in this

position it is able to avoid observation, and so escapes from large water birds which feed upon them.

The *ears* are located just behind the eyes and consist, externally, of the round tympanic membrane, which is connected with the internal ear beneath and also with the mouth cavity, by means of the eustachian tube.

Legs. The anterior legs are short and weak. They are provided with four inturned toes, which help little in locomotion but serve as supports to the body when on land. The hind legs, however, are enormously developed and adapted in several ways for leaping and swimming. The thigh and calf muscles are very powerful and are so attached to the hips that they move the legs as very efficient levers, in locomotion. Added to this is the great development of the ankle region and toes, which together are longer than the lower leg and add greatly to the leverage of these organs. Between the five long toes is developed a broad flexible web membrane, which accounts for the frog's notable ability as a swimmer.

Some frogs can leap fifty times their own length or twenty times their height, while a man, to equal this feat would have to make a broad jump of three hundred feet or clear the bar at a height of one hundred and twenty feet.

The legs of the frog are homologous to the paired fins of the fish but resemble much more closely our own arms and legs. A study of a prepared skeleton of the frog shows that the foreleg has the same regions as our arm. The hind leg even more closely resembles our leg, though with many differences due to being adapted for very different functions. Still the homology is plain as the following table shows.

COMPARISON OF APPENDAGES OF FROG AND MAN

Front leg and arm	Frog	Man
Upper arm (humerus)	Short and weak	Long and muscular
Lower arm (radius and ulna)	Short, bones united	Long, bones separate
Wrist (carpus)	Very short, stiff	Longer and flexible
Hand (metacarpus)	Turned inward	Straight
Fingers (phalanges)	Four, short and weak	Five, long and flexible
Hind leg and leg		
Upper leg (femur)	Very long and muscular	Medium length, not so muscular in proportion
Lower leg (tibia and fibula)	Very long, bones united	Medium length, bones separate
Ankle (tarsus)	Very greatly lengthened	Short
Foot and toes (metatarsus and phalanges)	Five, very long webbed toes	Five short toes, not webbed

Not only are the regions and the bones similar in general structure, but many of the muscles, blood vessels, and nerves of the limbs of man and frog are of similar form and name. The chief difference lies in the fact that man has developed his forelegs into organs for prehension (grasping) and no longer uses them in locomotion. This has resulted in his erect position and has produced many changes in structure to adapt the arm and hand for its altered function.

The muscles of the fish are in the form of flat plates, extending across the body and moving it as a whole, while in the frog, the muscle tissue is grouped into true "muscles" like our own, attached to bones by tendons, and acting on them as levers, thus marking a great advance in structure, and permitting greater variety of motions.

The Digestive System. The digestive system of any animal begins with the mouth, teeth, and food-getting adaptations which we have already described in this case.

A short gullet connects the large mouth cavity with the stomach which is an oval enlargement of the digestive tube, set diagonally in the body cavity and partly covered by the liver which is anterior and ventral to it. Continuing from the stomach is the intestine, of medium length, coiled, and enlarging near the vent into a short, broad rectum and cloaca. The digestive tract is longer than that of the fish, but the fingerlike projections (caeca) are lacking in the stomach, the absorbing surface being increased by the coiled intestine, instead. Connected with the food tube are the usual digestive glands, the salivary and mucous glands in mouth and gullet, gastric glands in the walls of the stomach, and the large liver and smaller pancreas opening into the intestines.

Here as usual we have the essential features of any vertebrate digestive system: a tubular canal, provided with large extent of surface for absorption by osmosis, and a series of glands which secrete the fluids used to get the food into soluble form for this absorption.

Circulatory System. In so complicated an animal as the frog, it would be expected that the circulatory system would need to be better developed than in the fish, especially as the lungs are present for the first time, to purify the blood. To provide for this added burden, we find a three-chambered heart located well forward in the body cavity, and consisting of two auricles and one muscular ventricle. Extending from the ventricle is a large artery which at once divides in two branches like a letter Y and each of the arms again divides into three separate arteries on each side. The anterior pair of these branches (the carotids) carries blood to the head; the middle pair arch around to the back of the body cavity and unite to form the dorsal aorta which supplies the muscles and viscera; while the posterior (pulmonary) arteries carry the blood to the lungs and skin for purification.

The blood supplied to the muscles returns laden with carbon dioxide and other oxidation products, while that going to the digestive tract takes up the digested foods as well. It returns by way of the veins, in part to the liver, and, finally, all to the right auricle of the heart. Meanwhile the blood which went to the

lungs and skin has been relieved of its carbon dioxide and re-supplied with oxygen, and this returns by the pulmonary veins to the left auricle of the heart. The blood from both the general and the pulmonary circulation then enters the ventricle, but by means of a complicated valve, that having most oxygen is sent to the head and brain. The next best goes out into the aorta, while that with most carbon dioxide is diverted into the pulmonary arteries and goes to the lungs and skin.

On each complete trip, some of the blood passes through the kidneys, so that all of the nitrogenous waste can be removed as urine. Really the purest blood in an animal's body is that which has just left these very important organs, even though it may have more carbon dioxide than when leaving the lungs.

The blood which returns from the digestive tract is gathered into a large vein (portal) and passes through the liver, where some food substances may be stored, and certain impurities removed, after which it flows back to the right auricle.

Several important differences will be noted in the frog's circulatory system, as compared with the fish. The frog's heart is three chambered and is located farther back in the body; the blood leaves the heart in *two* circuits, the pulmonary and the general, while in the fish, it makes only one continuous trip. In other words, the blood twice returns to the heart of the frog in any single complete circulation, and only once in the fish.

Respiration. In the larval form, as a tadpole, the young frog breathes by means of gills but the adult develops a pair of simple lungs, opening into the throat by a trachea and glottis. These lungs are rather cone-shaped, sac-like organs, whose inner walls are honey-combed with delicate air cells provided with many blood capillaries so that the conditions for osmosis are fulfilled.

The frog has no ribs or diaphragm to expand the lungs so that air may come in, and is therefore forced to "swallow" whatever air it gets by a sort of pumping motion of the throat which can be observed in any living frog. Air is taken in through the nostrils, which are then closed and the air "swallowed" by the action of the abdominal muscles. The elasticity of the lung tissue forces

the air out again. The slight throbbing of the throat is not breathing; it merely pumps air in and out of the mouth. When air is really "swallowed" the sides of the body expand and the floor of the mouth rises. Then the expired air is forced back into the mouth where the constant pumping, above mentioned, gradually

STRUCTURE OF FROG
— MALE —
(DIAGRAMMATIC)

CIRCULATORY ORGANS, ETC

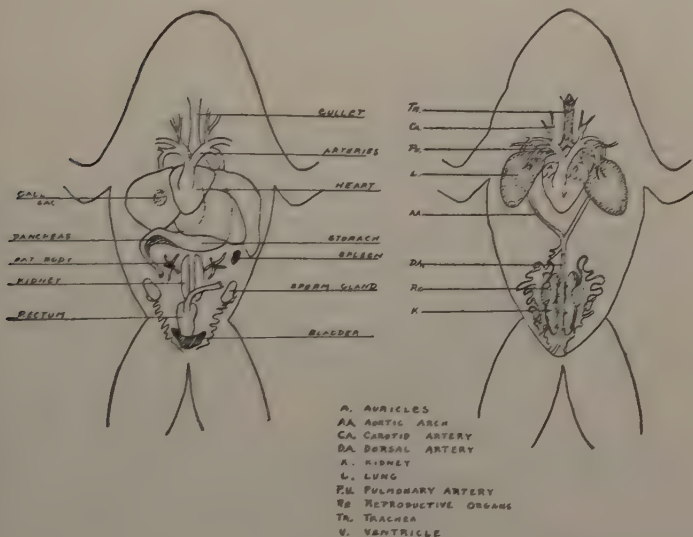


FIG. 91a.

replaces it with fresh air, which is then swallowed and the process repeated.

Considerable blood is aerated by the capillaries in the skin, which act as a sort of gill, obtaining dissolved oxygen when the animal is under water. This is an evident adaptation for its amphibious life.

Nervous System. The nervous system shows considerable advance over that of the fish. The cerebrum is larger compared with the other brain parts. The brain as a whole is more specialized

and more nearly fills the cranial cavity of the skull; while the spinal cord is shorter, thicker, and has its branches arranged much more like those of the higher animals.

Observation of the living frog shows that all the senses are fairly developed except possibly that of taste. Sight and hearing

ADAPTATIONS OF THE FROG

	By Means of	For the purpose of
External features	Protective color	Escape from enemies
	Shape, and slimy secretion	Locomotion and escape
Head	Large mouth	Catching food
	Location and shape of tongue and teeth	Catching food
	Nostrils at tip of nose	Breathing when partly submerged
	Projecting eyes	Vision when partly submerged
Limbs	Short fore limbs	Landing after leaping
	Long hind legs	Increasing leverage for leaping
	Very long feet and toes	Leaping and swimming
	Powerful muscles	Swimming
	Webbed toes	Swallowing
Digestive organs	Gullet and mucous glands	Digesting proteids
	Stomach and gastric glands	Digesting and absorbing all food stuffs
	Intestine, liver, and pancreas	Forcing blood through body
Circulatory organs	Three chambered heart	Bringing blood to heart
	Veins	Carrying blood from heart
	Arteries	Distributing blood to the tissues
	Capillaries	Transportation of food, oxygen, waste, CO ₂
	Blood	Absorbing dissolved oxygen
Respiratory organs	Gills in tadpole	Absorbing free oxygen
	Two lungs in adult	Increase of absorbing area
	Lung lining cellular	Carrying oxygen, etc.
	Rich blood supply	Taking air into lungs
	Throat and body muscles	Additional breathing when submerged
	Thin vascular skin	

are probably good, and its varied life on land and water necessarily presents a wider range of experiences and hence some advance in intelligence.

Excretory System. Excretion is provided for by a pair of well-developed kidneys with a large bladder. Water, uric acid, and other nitrogenous waste are removed by these organs, while the lungs and skin also help dispose of waste matter, particularly carbon dioxide and water.

Reproduction. As in the fish, the sexes are separate, and the reproductive organs are easily found upon dissection. The ovaries appear as masses of eggs, the size depending on the season of year. The sperm glands of the male are small oval organs near the kidneys. Both sets of organs have coiled ducts which eventually connect with the posterior part of the intestine (cloaca) into which the bladder also empties.

It may be well to remember that in the frog we find systems of organs adapted to perform all the life functions, and that in the higher animal forms, few new structures are developed, but rather, these are carried to a greater complexity or perfection.

The following list illustrates this and would apply in general to most vertebrate animals.

1. Digestive system

Mouth, tongue, teeth, throat cavity, salivary glands

Gullet and stomach, gastric glands

Intestine, small and large, rectum, and cloaca

Liver and gall sac, pancreas

2. Respiratory system

Nostrils, mouth cavity, glottis, and trachea

Lungs, air cells, and capillaries

Skin

3. Circulatory system

Heart, auricles, and ventricle

Arteries, aorta, etc.

Capillaries, and veins

Lymph vessels, and spleen

4. Excretory system
Kidneys, and their ducts (ureters), bladder
Lungs, and skin
5. Nervous system
Brain: consisting of
Olfactory lobes
Cerebrum
Optic lobes
Cerebellum
Medulla
Spinal cord and nerves
Sense organs, eye, ear, etc.
6. Supporting system
Skeleton, bone, and cartilage; ligaments
Connective tissue
7. Muscular system
Body muscles, tendons
Muscles of internal organs, heart, intestines, etc.
8. Reproductive system
Ovaries and oviducts
Spermaries and sperm ducts

COLLATERAL READING

General Structure: *Economic Zoölogy*, Kellogg and Doane, pp. 1-13; *Economic Zoölogy*, Osborne, pp. 356-374; *Biology of the Frog*, Holmes, entire; *Types of Animal Life*, Mivart, pp. 96-122; *Forms of Animal Life*, Rolleston, pp. 74-81; *Winners in Life's Race*, Buckley, pp. 70-88; *Reptiles and Birds*, Figuiet, pp. 17-33; *The Animal World*, Vincent, p. 25; *Textbook of Biology*, Peabody and Hunt, pp. 101-119; *The Frog Book*, Dickerson, pp. 171-185; *U. S. Fish Commission Report*, 1897, pp. 251-261; *Zoölogy Textbook*, Davenport, pp. 325-348; *Familiar Life*, Matthews, pp. 1-56; *Talk about Animals*, pp. 151-154, 160-164; *Wilderness Ways*, Long, pp. 75-87; *General Zoölogy*, Colton, pp. 181-195; *Zoölogy Textbook*, Linville and Kelly, pp. 327-347.

SUMMARY

Amphibia (two lives).

Characteristics:	metamorphosis	direct fertilization
	no scales	larva vegetarian
	three-celled heart	adult carnivorous
	fairly developed brain	

Representatives: Frogs, tree-frogs, salamanders, toads, newts.
Frog.

External Structure.

1. Shape, irregular, not graceful.
2. Covering, loose smooth skin, absorbs water.
Adapted for protection by color and slime.
Adapted for respiration by capillaries, thinness.
3. Head (no neck).
Nostrils anterior, connect with mouth, valve.
Mouth, large for catching insects.
Tongue, fixed in front, two tips, sticky.
Teeth, none below, small on upper jaw and roof.
Interior structure.
Nostril openings Eustachian tubes
Folded tongue, Gullet, trachea.

Eyes.

Large, projecting as protective adaptation.
Can be retracted, three lids.

Ears, flat drum on surface of head.

4. Legs. Anterior, short for support only.
Posterior, long, strong, for leaping and swimming.
Adaptations.
Powerful calf and thigh muscles.
Long levers, especially ankle and toes.
Webbed toes. Large hip bones.
Comparison with man (see text).
Legs homologous to paired fins of fish.
Legs homologous to legs and arms of man.
Legs and fins analogous (locomotion).
Legs and arms not analogous (prehension and locomotion)
5. Muscles. Spindle shaped as in higher animals.
Attached to bones with tendons.
Not in separate plates like the fish.

Internal Structure.

Digestion.

Food-getting adaptations	{	tongue, attachment, shape, sticky.
		teeth, upper jaw and roof of mouth.
		mouth, location, size.

Organs of digestion.

Gullet, short, broad (why?).
Stomach, oral, diagonal, covered by liver.
Intestine, medium length, coiled (why?), rectum.
Glands, salivary and mucous in mouth.
Gastric and mucous in stomach.
Liver } emptying into intestine.
Pancreas }

Essentials for digestive system.

Tubular canal.

Glands for secretion.

Devices to increase surface, for osmosis absorption.

Circulation.

Heart, location,

Three chambers, two auricles, one ventricle.

Arteries, carry blood from the heart.

Carotid, from ventricle to head, oxygenated blood.

Aorta, from ventricle to body, oxygenated blood.

Pulmonary, from ventricle to lungs, de-oxygenated blood.

Veins, carry blood toward the heart.

Portal-caval, from digestive system to right auricle, de-oxygenated.

Caval, from muscles, etc., to right auricle, de-oxygenated.

Pulmonary, from lungs to left auricle, oxygenated.

Blood changes in lungs, water, carbon dioxide, *out*, oxygen, *in*.

Blood changes in kidneys, water, urea, salts, *out*.

Blood changes in liver, impurities, bile, *out*, sugar changes.

Advance over fish.

Three-chambered heart.

Two circuits of blood, pulmonary and general.

Lungs instead of gills.

Respiration.

Gills in larval stage, lungs later.

Lungs, shape, location.

Wall structure, air cells, and capillaries (why?).

Action of lungs in breathing.

Air pumped into mouth by throat and swallowed.

No diaphragm (cf. man).

Air exchange in mouth, nostrils with valves.

Use of skin, how adapted for breathing.

Nervous System.

Brain larger, specialized parts, nearly fills skull.

Spinal cord thicker, shorter, with specialized branches.

Senses better (Ex. taste). Higher intelligence (why?).

Excretion.

Kidneys, shape, location,

function.

Lungs and skin.

What excreted by each.

Reproduction.

Ovaries.

Sperm glands.

Ducts.

CHAPTER XXIX

THE AMPHIBIA, LIFE HISTORY AND HABITS

Vocabulary

Caudal, pertaining to the tail.

Cellular, composed of cells.

Obscured, hidden.

Hibernate, to remain inactive over winter.

Eject, throw out.

Vicissitudes, changes and accidents of life.

Life History. The life history of a frog is a true metamorphosis and illustrates perfectly the development of an air-breathing land animal from a gill-using aquatic form.

The female lays the eggs in the water, early in the spring, and they are fertilized immediately, thus assuring more certain development than in the case of fish. Each egg is surrounded by a jelly-like coat which swells in the water until all are joined in a gelatinous mass. In this, dark-colored eggs about as large as peas can be seen, each surrounded by a transparent covering. The rate of embryo growth depends somewhat upon temperature and food conditions but usually the parts can be distinguished within each egg in less than ten days. The little tadpoles themselves leave the mass within two weeks.

At this stage they fasten themselves to stones by means of sucking discs and live by absorbing the attached egg yolk, no mouth being developed. There are three external gills, a narrow fish-like body, well developed, and a caudal fin.

Next they become free swimmers. The mouth now appears, and a very long coiled digestive tract begins work on the vegetable scums which are their food. Gradually a fold of skin grows backward over the gills, like an operculum, leaving only a small opening

on the left side. This has an internal connection to the right gills so that both are supplied with water.

These latter changes may have occupied nearly two months, and the tadpole is now a fish-like animal, with gills, lateral line, fins, two-chambered heart, and one-circuit circulation, but soon other changes follow, gradually adapting the aquatic animal for land life.

A sac-like chamber develops backward from the throat like the fish's air bladder, but soon separates into two lobes with cellular walls which we recognize as lungs. To correspond with this, the circulation is gradually modified; the gill arteries are changed to carotids, pulmonaries, and aortic arches; the heart becomes three chambered, and the circulation flows in two circuits. At this stage the tadpole may be seen coming to the surface for air to fill his new lungs as his gills no longer are used for breathing but are being modified into mouth parts and other organs.

While these notable changes are occurring to the respiratory and circulatory systems, others no less remarkable are taking place elsewhere. The mouth widens, teeth develop, and the intestine becomes shorter and larger to adapt it for animal diet which the young frog now begins to use.

The external changes, which have accompanied these last mentioned, have been more conspicuous, though less important, and are as follows. The tail is gradually absorbed (not shed), limbs develop at the place where it joined the body, and the body itself changes shape. The front legs begin growth about the same time but do not show so soon since they start beneath the operculum in the gill chamber and are smaller even when full grown.

By this time, the tadpole is a well-developed frog which comes on land, breathes air, eats animal food and gradually grows in size till he reaches the full stature of an adult. These latter changes have occupied usually another month, making a total of about three months for an average frog metamorphosis, though growth in size may continue much longer.

Representatives. Let us now briefly take up a few of the common representatives of the amphibia, which includes, besides the frog, the toads, salamanders, newts, etc.

Toads. The common toad is a much abused and little appreciated member of society: he suffers from many false accusations and his undeniably plain looks have obscured his many virtues. To begin with, toads do *not* cause warts; they do *not* "rain down"; they do *not* "eat their tails"; and they are never "found alive in solid rock" as some newspaper scientists would have us believe.

On the other hand, the toad is a very useful and interesting animal and makes a good pet. They destroy enormous numbers of harmful insects, though we seldom see them in action as they hunt at night, when their prey is abundant and their enemies, the snakes, are asleep. So valuable is their service in insect destruction that in Europe toads are regularly for sale to gardeners and others, to be turned loose in their premises to protect their crops.

They catch their food with the tongue, like the frog, but have no teeth. Their rough skin and dull color are protective in their resemblance to the earth in which they live. They can change color somewhat to match their surroundings and also will play dead, to escape observation. They never drink water, but absorb it through the skin and may store considerable for use during winter when they burrow in the earth and hibernate. It is this stored water that toads sometimes eject when handled.

They burrow rapidly *backwards* in a way hard to understand, but very efficient and will bury themselves, in a few minutes, if the ground be soft.

They breed in water as do the frogs, but spend the rest of their time on land. They also differ in other ways. The eggs are laid in long strands, not in masses; the tadpoles are small and nearly black and develop into toads at much smaller size than do frogs. They emerge from the ponds in thousands when about the size of the tip of your finger and it is these swarms of tiny toads that give rise to the idea that they have come down in the rain. During the breeding season they develop vocal powers of no mean extent, their song being a rather sweet and bird-like trill.

Their eyes are even more handsome than the frog's. Altogether,

the toad is a useful and interesting animal and should never be regarded with repugnance, much less, with enmity.

Tree Toads. Another member of the amphibia is the tree-toad or tree frog (*Hyla*) which, though common, is seldom seen, because of its almost perfect protective coloration. Its song however is familiar enough when the "peepers'" cheerful chorus ushers in the early spring. They vie with the chameleon in ability to change color to match their surroundings, green, gray, brown, yellowish, and even purple being among their varied disguises. It seems hardly possible that so loud a song can be sung by a tiny frog, little more than an inch in length, but if we are patient and successful enough to hunt one out with a lantern at night, the reason is clearer. The little *Hyla* can expand its throat into a vocal sac twice the size of its head, and with this enormous drum can produce its very remarkable music.

They are true tree climbers and on each toe have sticky discs by which they can climb safely on the bark of trees and even cling to glass. Their color, stripes, and shape protect them perfectly from observation.

The eggs are laid in April; and the tiny reddish tadpoles feed on mosquitoes. The adults include also ants and gnats on their menu, which ought to give them a place in our affection. A curious fact about their tadpole stage is that they often leave the water before the tail is nearly absorbed, being apparently able to breathe air earlier in their metamorphosis than do most other frogs.

Salamanders and Newts. The tailed amphibians, including salamanders, newts, and mud puppies, are less known than they should be. We have over fifty species in the United States, that being more than are found in any other country. A very common mistake, is to call these animals "lizards." They can readily be distinguished because a lizard is a reptile and has scales like a snake whereas the salamander is an amphibian and has a smooth skin like a frog.

One often finds, in moist woods, tiny brown or orange red creatures about three inches long, beautifully spotted with scarlet and black. These are newts and very curious and interesting little

fellows indeed. They can only live in moisture, and so are found after rains and in wet places, although in adult form they breathe air. They have the regular amphibian metamorphosis, though they never absorb their tails. The newt, however, adds a very curious stage to its life history, for after about two years of land life it returns to the water, even from great distances, changes color to olive-green, develops its tail fin again and by some means is enabled to breathe the dissolved air in the water. Here, after all these strange vicissitudes, breeding takes place, eggs are laid, and the life history starts again.

The true salamanders are larger, there being several common



FIG. 92. The western brown eft, or salamander, *Diemictylus torosus*.
From Kellogg.

species. The spotted salamander, black, with yellow spots, is about six and one-half inches long, and the black salamander, blue black and a little smaller, are two of the kinds most often found and mistaken for lizards. All are harmless to handle, useful as insect eaters and so helpless and interesting that they ought never to be destroyed.

COLLATERAL READING

Metamorphosis: *The Frog Book*, Dickerson, pp. 1-7; *Study of Animal Life*, Thompson, p. 258; *Elements of Zoölogy*, Davenport, pp. 451-457; *Textbook of Zoölogy*, Packard, p. 184; *Introduction to Biology*, Bigelow, pp. 389-414; *Lessons in Zoölogy*, Needham, pp. 178-196; *Elementary Zoölogy*, Kellogg, p. 299; *Biology of the Frog*, Holmes, pp. 81-119; *Animal Activities*, French, p. 179; *Zoölogy Text*, Packard, p. 874; *Winners in Life's Race*, Buckley, pp. 70-77; *Cornell Nature Leaflet*, Vol. 10, No. 1, pp. 88-97; *Life in Ponds and Streams*, Furneaux, pp. 360-399.

Relatives: *American Natural History*, Hornaday, pp. 359-374; *Frog*

Book, Dickerson, pp. 53-239; *Elementary Zoölogy*, Davenport, pp. 325-348; *Practical Zoölogy*, Davison, pp. 199-211; *Elementary Zoölogy*, Gallo-way, pp. 296-305; *Pet Book*, Comstock, pp. 246-259; *Handbook of Nature Study*, Comstock, pp. 181-199; *Nature Study Leaflets* (bound), pp. 185-206.

SUMMARY

Metamorphoses of Frog.

Meaning of term, other examples, tadpole is "frog larva."

Egg, laid in water, surer fertilization, in spring.

Gelatinous protection, *parts show in 10 days*.

Tadpole (attached stage). Discs, three external gills.

Lives on yolk. *Two weeks*.

Tadpole (free swimmer), mouth develops.

Long intestine because vegetable feeder (explain).

Lateral line, caudal fin, operculum with left opening.

Two-celled heart, fish-like. *Two months*.

Tadpole, frog.

Mouth widens, intestine shortens, teeth develop.

Heart three celled, arteries change from gill to lung.

Lungs develop, air used, skin breathing.

Tail absorbed, legs develop. *One month*.

Adult frog.

Total time about three months, depends on food, temperature, etc.

Representatives.

Frog.

Toad, false ideas, real value.

Adaptations for food-getting.

Tongue as in frog, no teeth.

Color, skill.

Distinctions from frog.

Toad

Eggs in strands

Nocturnal feeding

Tadpoles small, black

No teeth at all

Rough skin

Tree toad (Hyla).

Adaptations, color protection, color change.

Discs for climbing, vocal sacs.

Tadpoles reddish, early develop lungs, eat *insects*.

Salamanders.

Distinctions from lizards.

Salamander

Common

Smooth skin like frog

No claws on feet

Metamorphosis like frog

Harmless, useful and interesting.

Frog

Eggs in masses

Daytime feeding

Tadpoles larger, lighter

No teeth on lower jaw

Smooth skin

Lizard

Not common

Scaled skin like snake

Claws on feet

No metamorphosis

CHAPTER XXX

THE REPTILES

Vocabulary

Iridescence, changeable rainbow colors.

Reticulated, marked with a network pattern.

Retracted, drawn back.

Constrictors, snakes that crush their prey in their coils.

There is probably no group of animals less understood, and concerning which there is more abundant misinformation than the reptiles. It is principally to correct some of these false ideas that they are discussed here.

The reptiles include snakes, turtles, lizards, and crocodiles and



FIG. 93. A fence lizard, *Sceloporus occidentalis*. From Kellogg and Doane.

the points in which they differ from amphibians are as follows:

1. They never breathe by gills at any stage.
2. They have no metamorphosis.
3. Eggs are internally fertilized and have a shell, or young may be born alive.
4. The body is covered with scales.
5. Feet, if present, are provided with claws.

False Ideas about Snakes. Of all the reptiles, the snakes are the objects of more ignorant superstition and foolish prejudice than any other form. To begin with, snakes are not "slimy" and "nasty." Their skin is as clean as yours and feels cold merely because of their lower bodily temperature. Snakes as a class are absolutely harmless and positively useful. Out of the numerous species inhabiting the United States only the rattler, copperhead, moccasin, harlequin, and coral snakes, are dangerous to handle. Snakes cannot jump from the ground when they strike nor do they spring from a perfect coil. A snake's tongue is not a weapon nor harmful in any way. It is an organ of touch *only* and is thrust out merely to feel its surroundings. The process of death is slow in any animal with a low nervous organism, and though reflex motions persist in a snake long after death, the setting of the sun has absolutely nothing to do with its death. Snakes do not swallow their young to protect them; "hoop snakes" do not roll like hoops; horsehairs do not turn into snakes; and rattlers do not add one rattle per year, but usually two or three, though some may be broken off. Removal of fangs from a poisonous snake does not render it harmless since other teeth take their place almost at once. Many snakes hiss; some as loudly as a cat. Most snakes can swallow prey larger than themselves. All snakes are muscular, graceful, and usually swift of motion, while many are very beautiful.

"There is no living creature which displays such a beautiful pattern of colors and rainbow iridescence, as the reticulated Python of the East Indies," says Wm. T. Hornaday.

Children are not born with any natural fear of snakes and adults should never be allowed to terrify their minds with silly snake stories and untrue and ignorant statements.

Adaptations. Another matter which is little appreciated in regard to snakes, is the fact that there is perhaps no other animal, except the bird, with a more highly specialized structure.

The whole animal, but particularly the head, is adapted for its peculiar habit of catching and swallowing prey actually larger in diameter than its own body. For this purpose there are numerous

sharp, incurved teeth on three sets of jawbones, any of which will grow again to replace those that may be broken or torn out. The lower jaw is not fixed directly to the skull, but is attached to a separate bone, the quadrate, which in turn is attached to the skull, thus permitting the jaw to move forward and backward, as well as up and down. This enables the snake to literally crawl outside of its victim, the upper teeth holding firmly while the lower jaw is advanced; then the upper jaw takes a new hold, and so on. The process is slow, often occupying hours, but there is no chance for escape of the prey. The snake's teeth cannot bite the food in pieces, so all its victims must be swallowed whole. To permit this, the various bones of the skull, so solid in other animals, are loosely attached in the snake, allowing the head to expand when swallowing is taking place. The two halves of the lower jaw are attached together by an elastic ligament which allows them to open sidewise, so that the lower jaw is capable of three motions, up and down, back and forward, and (each half) sidewise.

The process of swallowing is so long that special adaptations are provided to permit breathing to go on. The trachea may be extended along the floor of the mouth, almost to the teeth, so that air may reach the lungs, and moreover there is a large air chamber behind the lung to store air for this purpose.

The gullet and stomach are highly elastic and the digestive fluids very active, to accommodate food in such large doses. The flexible ribs and lack of breast bone or limb girdles allow for the passage of these enormous mouthfuls.

The delicate and slender forked tongue is protected during swallowing by being retracted into a sheath. Its function is for touch, rather than taste, which sense would be of very little use to an animal which eats its food whole and sometimes alive.

Snakes obtain their food in three general ways: they may catch it with the teeth and swallow it at once as does the common garter snake; they may crush the prey in their coils, before swallowing, as do all constrictors; or they may have poison apparatus developed, which stupifies or kills their victim immediately.

Poisonous Snakes. While, fortunately, there are few poisonous snakes in the United States, their adaptations are very interesting. The long front teeth of the upper jaw are either grooved or hollow fangs, moveable in some snakes and fixed in others. These fangs are connected with salivary glands which, in this case, secrete the poisonous venom, and are so arranged that the act of striking, compresses the gland and forces the venom into the wound made by the fangs.

In common with most ideas about snakes, a great deal of nonsense is current regarding the frequency and deadliness of the bite of a poisonous species. To begin with, in all the United States the annual death rate from snake bite is about two. Second, all snake bites are not necessarily fatal. Third, unlimited whiskey is not an antidote.

The facts of the case are about as follows, summarized from two eminent authorities, Doctor Stejneger and W. T. Hornaday.

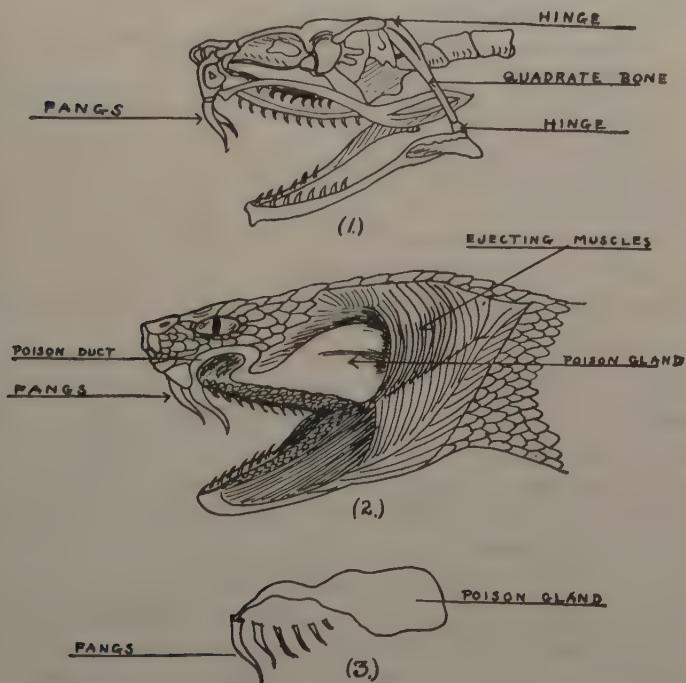
Learn to recognize and avoid three snakes: rattlers, copperheads and water moccasins. In all the United States there are but five poisonous types, and the three mentioned are rare except in certain localities. The rattlesnake is a fair fighter, never seeks trouble, strikes only in self-defense, and always warns before attacking, so that, with any reasonable care, it may easily be avoided.

The copperhead goes by other names, sometimes being called the "pilot snake" or "deaf adder," and as it attacks without warning, is actually more dangerous than the rattlers, though slightly less poisonous. It is usually found in the woods, is seldom over three feet long, and is beautifully colored with broad bands of old copper on a background resembling new copper. Any snake remotely resembling this description is to be avoided.

Treatment of Snake Bites. Bites are, fortunately, generally received on the arms or legs, and are not necessarily, nor usually fatal if properly treated. Campers in snake-infested regions can obtain for five dollars or less, an outfit consisting of a hypodermic needle, chromic acid solution, permanganate of potash, and liquid

strychnine, which with the anti-venom serum, now easily obtained, constitute almost sure protection.

POISON APPARATUS OF SNAKE.



After Linville and Kelly, by permission of Ginn and Co.

FIG. 94. Poison Apparatus of Snake.

Fig. 1 shows the structure of the skull. Note the two hinges which permit a forward and backward motion of the quadrate bone. This allows the lower jaw to be extended and drawn back to aid in swallowing the prey.

The very loose attachment of all the skull bones permits great freedom of motion, needed when swallowing a victim larger than itself.

The fangs are grooved or hollow, forming an outlet for the poisonous venom.

Fig. 2 shows part of the head dissected away to expose the poison gland and the muscles that press upon it when the snake strikes. The act of striking forces the venom out through the fangs, into the wound.

Fig. 3 is a diagram showing the poison gland, duct and fang removed. Also the secondary fangs which develop to replace the large ones, if they are injured or torn out in striking.

In case of accident, the treatment should be as follows:

1. Cut the wound to promote free bleeding.
2. Tie a ligature above the wound.
3. Use anti-venom serum if at hand.
4. Give alcoholic stimulants in frequent, *small* doses: an excess may cause death.
5. If no serum is available, inject either the chromic acid or permanganate.
6. Inject liquid strychnine (15–20 minims) every twenty minutes until spasms begin.
7. Ligature must be loosened at times to allow the circulation of enough blood to prevent mortification.
8. Summon a doctor if possible, but it is the treatment of the first hour that counts.

When you realize that only about two in over 100,000,000 persons die of snake bite in the United States, — that we have few venomous kinds of snakes in this country, and finally, that rational treatment is usually successful, you can see how foolish is the fear and hatred so often shown toward these really useful and handsome animals.

Solomon selects as one of the mysteries of nature, “the way of the serpent upon the rock” and surely their adaptations for locomotion are peculiar enough to warrant this distinction. They have no legs, yet they travel, climb, and swim with ease and rapidity. They accomplish these feats by means of the broad plates on their ventral surface. These plates have their free edge toward the rear, so will catch against the slightest roughness. To each plate is attached a pair of ribs which operate somewhat as legs, with each plate as a foot. To allow free motion of the ribs, the vertebrae have a very flexible ball-and-socket joint, and the whole body is provided with exceedingly strong muscles, so that a snake really travels on hundreds of muscular legs (ribs).

This is a good example of analogy, the ribs and plates performing the same function as legs, but being of entirely different origin and structure.

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SUMMARY

Representatives.

Snakes, turtles, lizards, crocodiles, and alligators.

Characteristics.

No metamorphosis nor gills.

Eggs internally fertilized.

Scales, claws, young may be born alive.

Erroneous Ideas.

Not dirty nor dangerous, clean and useful.

Reason for "cold" feeling. Rattles per year.

Tongue for feeling only. Fangs, hissing.

Reason for slow death, "hair snakes," "hoop snakes."

Adaptations.**Food-getting, methods.**

Caught by teeth and swallowed (garter snake).

Crushed before swallowing (boa constrictors).

Venom to kill or stupefy (rattler, cobra).

Adaptations for food-getting.

In-curved teeth, jaw attachment.

Elastic skull and jaw.

Tongue sheath, protrusible trachea, air sac.

Elastic gullet, strong digestive fluids.

Adaptations for locomotion.

Rib attachment to ventral plates.

Ventral plates (scutes).

Flexible spinal column.

Analogy between legs and ribs.

Poisonous snakes.

Apparatus, fangs, hollow or grooved teeth.

Fangs movable or fixed.

Poison from modified salivary glands.

Muscles for ejection of venom.

Kinds.

Rattle snakes (several species) known by rattle.

Copperhead (pilot or deaf adder) known by color.

Water moccasin (found in southern swamps, large).

Treatment of snake bites.

Promote bleeding.

Ligature above wound if possible.

Use serum or permanganate of potash or chromic acid.

Stimulate with little alcohol or strychnine.

CHAPTER XXXI

BIRDS, THEIR STRUCTURE AND ADAPTATIONS

Vocabulary

Flexible, easily bent.

Impair, to interfere with.

Competent, able.

Concave, curved in.

Eliminate, to excrete or throw off, as waste.

Coördinate, to make to work together.

Acute, keen.

The group of birds is one of the most familiar, useful, and interesting, of all the animal kingdom. Among the vertebrates they are the most highly specialized in structure, every organ being adapted for the one object, namely, flight.

Birds are sharply distinguished from all other animals by the following points, among many others:

1. Their body is covered with feathers.
2. Their forelimbs (arms) are developed as wings, solely for locomotion and never for prehension.
3. The mouth is provided with a horny, toothless beak.
4. The body is supported on two limbs only (like man).

Adaptations for Flight. The general smooth *outline*, due to the thick covering of feathers, permits easy and swift passage through the air with little resistance. The flexible neck and legs provide for easy "fore and aft" *balance*, while the wings, being attached high above the bulk of the body, prevent danger from tipping over sidewise. *Lightness* is secured by very slender, hollow, air-filled bones, with few heavy joints; by numerous air sacs scattered through the body; by feathers for covering and locomotion; and

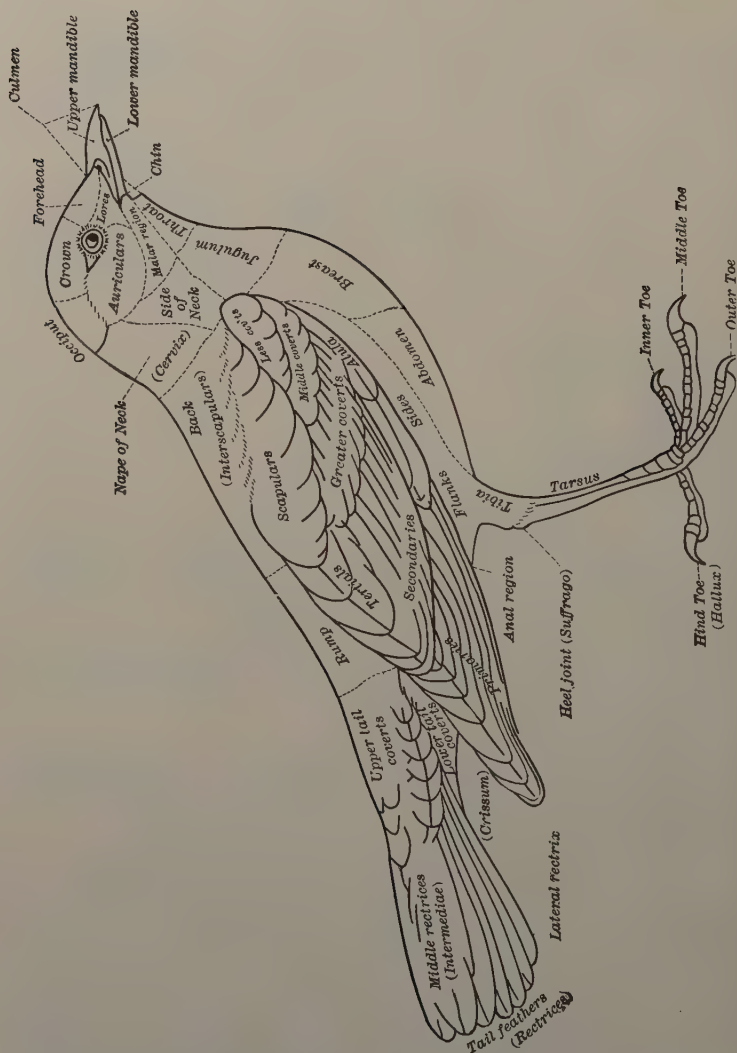


FIG. 95. Diagrammatic outline of bird's body with names of external parts and regions. From Kellogg.

by having teeth replaced by the light but strong beak. The chief flight adaptations, however, are the structure of the feathers and the wing. These will be discussed somewhat in detail.

Feathers. Feathers are modified forms of scales and develop in the same way from the skin. Some unchanged scales are always found on the feet and legs, which remind one of their relationship to reptiles. They are not evenly distributed over the bird's body, but are found in certain feather tracts, between which the skin is nearly bare, though the overlapping feathers do not reveal it. There are three kinds of feathers; the soft down which retains bodily heat, the ordinary body feathers that give the smooth and graceful outline to the otherwise angular form, and the large quill feathers of the wing and tail.

These latter are the ones concerned in flight and consist of a broad *vane* spreading from an axis (the *rachis*) terminating in a hollow quill. The vane is made up of innumerable rays called barbs, each like a tiny feather, having projections called barbules (little barbs) which in turn are held together by interlocking hooks of microscopic size. This complicated arrangement provides a vane which is very strong, light, and elastic, and furthermore, if the barbules become unhooked as when a feather is "split" by accident, the bird merely shakes them or draws them through its beak, and the feather is whole again. This is a great advantage over a wing membrane such as is possessed by the bats which, if once injured, cannot be repaired.

The rachis is grooved and the quill hollow, both being adapta-

FEATHER STRUCTURE.

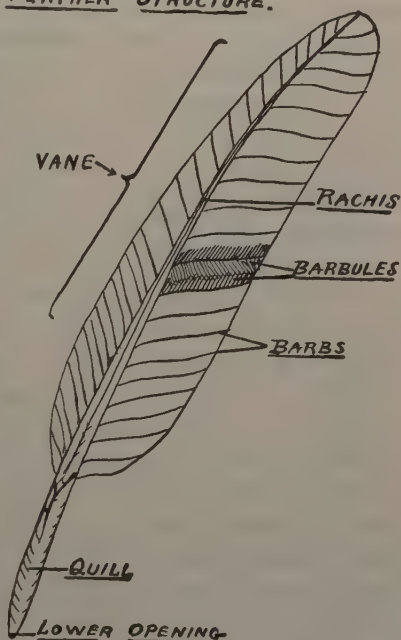


FIG. 96. Structure of quill feather.

tions to secure greater strength and less weight. At the base is an opening through which nourishment was supplied during its growth. The vane of the wing feathers is wider on one side of the rachis than the other. When the wing strikes against the air it tends to turn up, but rests against its neighbor and is held flat, while on the return stroke it is free to turn. The air passes through the wing as each feather partly turns on its axis ("feathering") and the wing meets less air resistance.

Uses of Feathers. The feathers provide the means of flight, and aid in easy locomotion, by giving the angular body a smooth outline. Moreover feathers, being one of the best heat-retaining substances, serve to keep the bird warm, even in the coldest weather, no matter how high or swift its flight. Their great activity necessitates their high body temperature and the feather covering retains this heat and makes possible their life in the upper air. The feathers of most birds are oiled by a secretion taken from a gland near the tail and spread on them by the beak. This makes them waterproof and is best shown in swimming and diving birds, which can spend hours afloat and suffer no discomfort.

Feathers have a further use in providing a colored covering which helps birds in escape from discovery by enemies because of its resemblance to their surroundings. This coloring may also be used to attract mates.

Moulting. Birds shed their feathers at least once a year, so that new ones may replace any that are lost or damaged. This is especially important in the case of wing feathers. Some species moult twice annually and may have differently colored plumage at different seasons. This change of color is sometimes used for protection and sometimes to attract mates. Wing feathers are shed in pairs and gradually, so as not to impair flight.

SUMMARY OF USES OF FEATHERS

1. Flight.
2. Giving regular body outline.
3. Protection from cold and water.
4. Protective coloration.

The Wing. The wing is almost as wonderful an organ as the human hand, but although a modified arm, it has lost all power of grasping and is adapted entirely for flight. The shoulder is strongly braced by three bones, instead of two as in man, to withstand the tremendous pull of the powerful muscles. There is the shoulder blade, the collar bone ("wish bone"), and the coracoid bone extending to the sternum (breast bone). All three are devoted to supporting the wing, using a sort of tripod arrangement, which is very strong. The upper and lower arm bones are long, strong, and slender. The wrist is lengthened as are also the fingers; only three are present, however, the other two being sacrificed for lightness. Thus we have a long, three-jointed lever, firmly attached to the shoulder with its leverage greatly increased by the feathers. The problem now consists of providing the necessary muscle to swing such an arm.

Power Required. To illustrate the difficulty involved, we may take as an example the pigeon. It weighs about a pound and has a wing spread of about two feet. This would mean that a boy or girl of ordinary weight would have to swing through the air a pair of wings each from fifty to seventy-five feet long at the rate of two hundred to five hundred strokes per minute. Try to swing your own arm at this rate for a minute, and then imagine the power needed for a wing as long as a building lot front. If we think of keeping up this form of exercise for forty-eight hours without rest, we will have some idea of the bird's problem, and the marvelous way in which it has been solved.

Muscles, competent for this task, could not be located on the wing itself, as that would too greatly increase its weight, so we find the breast bone enormously enlarged and attached to it,

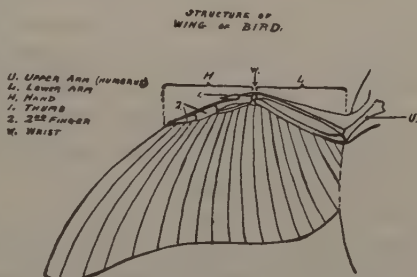


FIG. 97. Wing structure of bird.

muscle tissue equal in some cases to one-third the whole weight of the bird. To connect these muscles with the wing bones, a very remarkable set of tendons pass over the shoulder joints like ropes over pulleys and transmit the motion to the wing, much as our fingers are closed by muscles located in the forearm.

Shape of Wing. The attachment of the feathers to the wing is no less perfectly adapted for its purpose. The longest feathers (primaries) are attached to the fingers where their leverage will be greatest. Back of them come the secondaries, which brace them at the base and cover the spaces between their quills. These in turn are further supported by other rows, both above and below. The outline of the wing as a whole, with its concave under surface, thick forward edge, and thin flexible rear edge and tip, has just the form which man has recently discovered best for his aeroplane, and is beginning feebly to imitate.

Flight. In ordinary flight the wing stroke resembles horizontal figure eight — down and back, up and forward. The soaring of birds, like the hawk, where they seem to fly without any motion at all, is not understood. It may be due to slight wing motion, to balancing, or to utilization of wind currents, but so far, man has not satisfactorily explained, much less imitated it.

When man flies in the aeroplane, of which we are so proud, he flies not like the bird, with beating wings, but rather like the locust or beetle with stiff planes and a propeller behind. Thus far we have no engine powerful enough to swing a vibrating wing machine, large enough to carry a man in flight like a bird.

Muscles. The “white meat” of a chicken is the mass of breast muscles used in flight and the large breast bone with its projecting ridge is familiar to all of us. This ridge gives additional room to attach the powerful muscles. The outer layer of the white meat separates easily from an inside portion, this latter being very tender. The explanation is that the outer, larger, and tougher muscle was the one used in pulling the wing, down and backward in the “stroke” of flying, while the inner and more tender muscle acts by way of a tendon over the shoulder to raise the wing for

the next stroke, a much easier task and one which does not toughen it.

Adaptations for Active Life. The act of flight requires more work than any other form of locomotion. This is shown by the enormous breast muscles that operate the wings, and the general activity of the bird's whole life. Great amounts of energy are required which means large food-getting and digestive ability. This, in turn, demands a remarkably complete respiratory system to provide for rapid oxidation and release of energy.

Digestion. Birds are provided with a crop for storage, a gizzard in which small stones take the place of teeth for chewing, and very powerful digestive fluids, all of which work together to care for the vast amount of fuel needed to run so powerful an engine. A bird usually eats several times its own weight of food every day, so the common expression to "have an appetite like a bird" is hardly a suitable comparison for a light eater.

Respiration. The respiratory organs consist of very finely cellular lungs; behind these are the air sacs which hold the reserve air and permit all the lung tissue to be used in supplying oxygen to the blood. These air sacs also aid in this process. The rate of respiration is very high and the normal temperature is from 102 to 110 degrees, which would be fatal to man and to most other animals. Rapid oxidation means rapid production of waste matters and these are removed largely by the very highly developed lungs, there being little liquid urine eliminated by the kidneys, and no sweat glands. Crystals of urea are excreted by the kidneys.

Not only do the lungs provide the blood with oxygen for oxidation, and also remove waste, but in addition supply the air for singing, of which many birds require a large amount. It might be of interest to mention that the bird's song is not produced in the throat, but at the base of the trachea where the tubes from each lung join. Here is located the "song box," a very delicate and highly adjustable structure.

Circulation. To transport this large burden of digested food, oxygen, and the waste products of oxidation, there is required a

very large powerful heart and well-developed blood vessels. The rate of the heart beat is also very rapid.

Other Adaptations. Since the bird has devoted its forelegs (arms or wings) to flight, it must needs balance the body on the other pair, a thing which is done by no other group of animals except man. As an adaptation for this, the legs are attached high on the hips, so the body hangs suspended between them like an ice pitcher. This prevents any tendency to lose balance when walking, and permits the bird to bend easily and to pick up food, which has to be done with the beak since the fore limbs cannot be used for prehension.

Man, although he can balance on two legs, falls easily and has to learn to walk, but no one ever saw a bird fall down, or have any difficulty in walking. The difference is due to the fact that the bulk of man's body is *above* the point of support at the hips, while that of the bird swings below.

Perching. The bird usually perches on a support when at rest or asleep and for this purpose has a very curious arrangement. The tendon that closes the claws passes over the leg joints, hence the more the leg is bent, the tighter the claws close up. Thus when the bird settles down on a branch to sleep, the more it relaxes and the more its legs bend, the closer the claws grasp the perch. This and the balancing adaptations enable them to cling to a swinging twig when awake, or to a perch when asleep, with no possibility of falling.

Neck. The very flexible neck is another adaptation, especially for food-getting, since the wings cannot be used for that purpose. Not only is the bird balanced so as to bend easily but the length of the neck corresponds to that of the legs; because of this the bird can always reach the ground to pick up food.

Feet. The feet of birds differ widely in structure, depending on the particular purpose required, and are a splendid example of adaptation in themselves.

The common perching birds have three toes in front and one behind. Climbing birds, like the woodpecker and parrot, have two on each side, while swimming birds may have each toe with a

separtae web like the coot, or a web connecting all four, like the pelican, or only the front three, like the ducks and geese.

The birds of prey (hawks, owls, and eagles) have the toes provided with powerful claws and muscles which constitute their "talons" for catching food. While at the other extreme are birds like the swifts, hummers, and whip-poor-wills, which have very tiny and weak feet, since they live on insects or nectar, and spend most of their time in the air.

Birds which wade along the shores in search of food have long, slender legs, like the heron, snipe, crane, and plover, while in diving birds, such as the loon and duck, the legs are so short and so far back as to make walking very awkward.

Beaks. Just as great a range of adaptation is shown by the beak of the bird. In all cases it is light, strong, and horny, thus avoiding weight. With each class of birds the beaks vary, depending on the nature of their food and the manner of catching it.

The hook-shaped, strong beak of the hawk and owl is a familiar adaptation for the birds of prey while the very sharp, chisel-shaped beak of the woodpecker enables him to drill deep into the trees for nest holes and for food. Birds like the swifts, nighthawks, and whip-poor-wills, which catch insects on the wing, have weak but enormously wide beaks, often surrounded by hairlike feathers, making a regular trap to catch their food. The duck's wide beak with toothed edges is provided for scooping food from the mud and straining it out between the notches when the head is shaken, while the slender and sensitive beak of the snipe is used to probe in the mud for single pieces of food. Parrots use their short-hooked beak for defense, food-getting, and for climbing. Sparrows and finches have short straight beaks for crushing seeds. The crossbill has developed a real pair of pliers for opening cones, which contain the seeds he eats, while at the other extreme is the humming bird with its delicate tubular beak, able only to suck the nectar of flowers.

Nervous System and Sense Organs. To properly coördinate and control so complicated and highly adapted an organism, a well-developed brain is necessary. In birds, for the first time, the

brain completely fills the skull; the cerebrum is broad and the cerebellum especially large, as is to be expected in so active an animal.

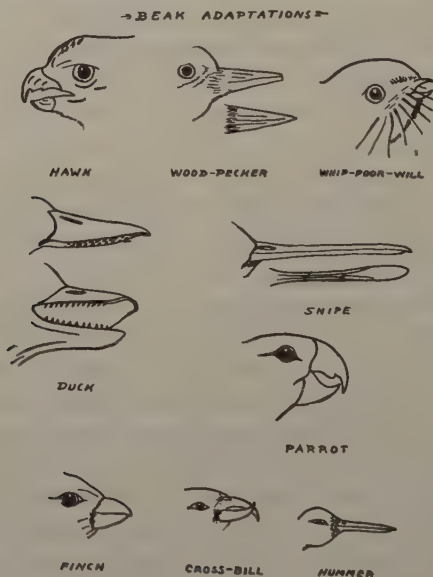


FIG. 98. Bird Beak Adaptations.

Hawk, powerful, sharp beak for catching prey.

Woodpecker, chisel edged, for chipping wood.

Whip-poor-will, weak beak but wide mouth, surrounded by stiff hairs, for catching insects on the wing.

Duck, wide beak with toothed edges, to dig up mud etc. and by shaking the head, sift out the waste.

Snipe, slender and sensitive, for probing after food in the mud along the shore.

Parrot, hooked and strong for climbing, and defense.

Finch, short and strong, for cracking seeds.

Cross-bill, a special device for opening cones to get seeds.

Humming bird, slender to suck nectar from flowers.

(After Wright and Coues.)

The optic lobes are also well developed but the olfactory (smell) lobes are usually small and the sense of taste is poor, since the food is swallowed without remaining in the mouth to be chewed and tasted.

The bird's eye is a very wonderful instrument, the sight being keen both at a distance and for close vision, and the change of focus is very quickly made. This is necessary in birds, because they must see clearly to pick up food at their feet, or detect an enemy at a distance, observe their prey far off, or weave a nest close at hand, and their ability along this line is unequaled by any other animal.

Their hearing is usually acute though there are no external ears, the openings being protected by a ring of feathers. Keeness of this sense is useful to escape danger and to recognize the songs and calls of their mates.

COLLATERAL READING

General Structure: *Textbook of Zoölogy*, Parker and Haswell, pp. 357-366; *Textbook of Zoölogy*, Shipley and McBride, pp. 495-506; *Winners in Life's Race*, Buckley, pp. 123-130; *Forms of Animal Life*, Rolleston, pp. 46-66; *Textbook of Zoölogy*, Claus and Sedgwick, pp. 232-238; *First Book of Zoölogy*, Morse, pp. 174-180; *General Zoölogy*, Colton, pp. 208-221; *General Zoölogy*, Linville and Kelley, pp. 364-373; *Elementary Zoölogy*, Davenport, pp. 370-419; *Elementary Zoölogy*, Needham, pp. 211-237; *Practical Zoölogy*, Davison, pp. 226-261; *Elementary Zoölogy*, Kellogg, pp. 327-372; *Biology Text*, Peabody and Hunt, pp. 62-100.

Flight of Birds: *Animal Mechanism*, Pettigrew, pp. 209-278; *Animal Locomotion*, Marey, pp. 103-206; *Winners in Life's Race*, Buckley, pp. 130-135; *Animal Life*, Thompson, pp. 123-124; *Textbook*, Shipley and McBride, pp. 501-502; *Introduction to Zoölogy*, Davenport, pp. 310-311.

Classification and Types: *Economic Zoölogy*, Kellogg and Doane, pp. 273-294; *Birds of Eastern North America*, Chapman, entire; *Bird Life*, Chapman, entire; *Citizen Bird*, Wright, entire; *Textbook of Zoölogy*, Linville and Kelley, pp. 374-397; *General Zoölogy*, Colton, pp. 222-245; *Types of Animal Life*, Mivart, pp. 66-95; *Little Brothers of the Air*, Miller, entire; *American Natural History*, Hornaday, pp. 171-309; *N. Y. State Museum Memoir*, Vols. I and II, entire; *American Geographic Magazine*, bird numbers, entire; *Bulletins of U. S. Department of Agriculture*; *Bulletins of Audubon Society*; *Bird Guides* (Land Birds, Water Birds), Reed, entire.

SUMMARY

Characteristics.

Feathers, wings, beak, two feet, shelled egg.

1. Adaptations for flight.

Shape, feathers to smooth outline.

Balance, neck, legs, attachment of wings.

Lightness, hollow bones, air sacs, feathers, beak.

Feathers.

Origin, modified, scales (other epidermal structures).

Distribution, tracts.

Kinds, down for warmth.

Regular feathers for outline.

Quill feathers for locomotion.

Structure.

(1) Vane, barbs, barbules, hooks.

Advantages: lightness and ease of repair.

(2) Rachis, grooved for strength.

(3) Quill, hollow for strength lightness.

Shape, one sided for "feathering."

Uses, flight, contour, warmth, color, to shed water.

Moulting, for repair replacement and color change.

Wing, homologous to hand, not analogous.

Bones, three shoulder bones in tripod form.

Shoulder blade, narrow.

Collar bone (wish bone) united.

Coracoid, to breast bone, special for flight.

Arm bones long and slender.

Hand reduced to three fingers (why?).

Muscle power.

Muscles not on wing (why?), cf. human hand.

Breast muscles one-third weight.

Outer and inner layers (white meat).

Large ridge on breast bone.

Tendons and pulleys at shoulders.

Shape of wings.

Feather arrangement, why longest feathers at end?

Concave below, flexible rear edge and tip.

2. Adaptations for active life.

Much energy, oxidation, food, food-getting, digestion, respiration, circulation, excretion.

Digestion.

Crop for storage, flockwise feeding.

Gizzard for grinding in place of teeth (why?).

Powerful digestive fluids.

Respiration.

Lungs finely cellular (why?).

Air sacs for reserve air, air in bones.

High rate of breathing and temperature.

Excretion via lungs.

Use of air in song, location of syrinx.

Circulation.

Heart large, four chambered, rapid beat.

Blood vessels, large, especially to breast.

3. Other adaptations.

- (1) Attachments of legs for balance (cf. man).
Ease of picking up food, since no hands present.
- (2) Perching.
Tendon action.
- (3) Neck, flexible and muscular (why?).
- (4) Feet.

Structure of toes	Examples	Adapted for
3 front; 1 rear	Song birds	Perching
2 front; 2 rear	Woodpecker	Climbing
	Parrot	
All webbed, separate	Coot	Swimming
All webbed, united	Pelican	Swimming
Three webbed, united	Duck, goose	Swimming
3 front; 1 rear, heavy claws	Hawk, owl, eagle	Catching prey
Small, weak	Hummer, swift	Little used
Long legs	Crane, heron	Wading
Legs short, far back	Loon, duck	Diving

5. Beaks. (Why not teeth).

Kinds	Examples	Adapted for
Hooked	Hawk, owl	Catching prey
Chisel shaped	Woodpecker	Drilling in trees
Wide but weak	Night-hawk	Catching insects on wing
	Swift	
Broad and notched	Duck	Scooping and straining
Slender and sensitive	Snipe	Probing in mud
Notched and hooked	Parrot	Climbing
Short and thick	Sparrows	Seed-eating
Crossed mandibles	Crossbill	Opening cones
Slender tube	Hummer	Sucking nectar

6. Nervous system.

- Highly developed (why?).
- Brain fills skull.
- Cerebrum, cerebellum, and optics large.
- Taste and smell not acute (why?).
- Sight keen, wide range of focus.
- Hearing keen for escape and recognition (song).

CHAPTER XXXII

BIRD HABITS

Vocabulary

Unmitigated, having no redeeming feature.

Excavated, dug out.

Inaccessible, hard to get at.

Stringent, strict.

Feeding. As before mentioned, their intense activity requires that birds obtain large amounts of food. Almost every thing that can be eaten comes to the table of some kind of bird, certain ones eating animal food exclusively, others are strict vegetarians, while many use a mixed diet.

Among those using animal food are large birds of prey, such as hawks and owls, which feed upon rats, rabbits, field mice, and other small animals, also upon some other birds. Then there are many whose diet is largely or entirely fish, which they catch by diving, as do the loon, grebe, pelican, and kingfisher. Some, like the vulture and buzzard, are scavengers and eat any dead animal that they can find; such birds have sight very keenly developed. Probably the largest number of birds which enjoy an animal diet live chiefly on insects which they may catch on the wing (swifts), by burrowing (woodpeckers), from the ground (robins), or on trees (warblers).

Many birds live almost exclusively on seeds, doing much good by the destruction of weed seeds while others, such as blackbirds and bobolinks, do considerable damage by their preference for grain, peas, and rice. Various kinds of both wild and cultivated fruits, especially berries, are preferred by certain birds for all or part of their bill of fare, though usually the fruit-eaters have to change to an insect diet during seasons when fruit is scarce.

It sometimes happens that birds enjoy the same seeds or fruits that man raises, or they may at times rob his yard of a stray chicken, but very careful study has proven that there are but three or four birds which do more harm than good. The rest many times repay for their fruit by destruction of insects and vermin. The birds in whose favor little can be said are the Cooper's and sharp-shinned

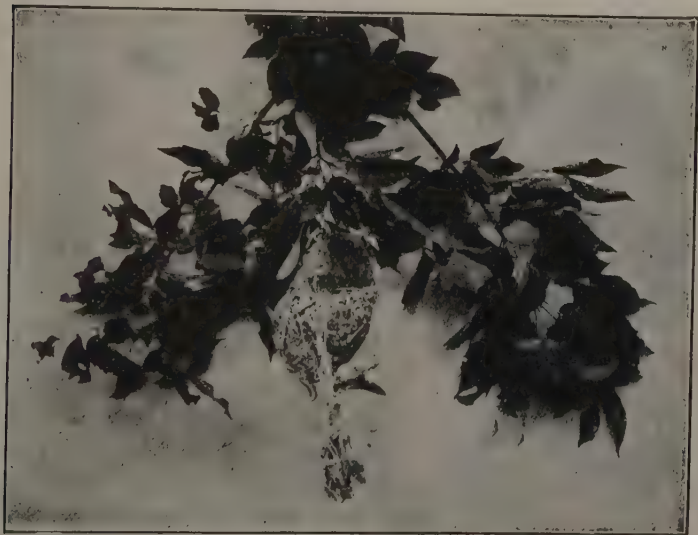


FIG. 99. Oriole's nest with skeleton of bluejay suspended from it, the blue-jay probably came to the nest to eat the eggs, became entangled in the strings composing the nest and died by hanging. Photograph by J. S. Hanter. (From Kellogg.)

hawks, great horned owl, and English sparrow. The verdict against the first three is based upon their destruction of poultry and useful birds, while the sparrow is driving away many of our more valuable and attractive native birds.

The English sparrow and possibly the starling also are examples of the un wisdom of tampering with the balance of nature. Both are European birds, introduced into this country by man. Abroad they are not over numerous, but here, removed from their natural

enemies, they multiply unchecked and are becoming an unmitigated nuisance.

Nest Building. The fact that the bird's egg requires continuous external heat for hatching is a point in which they differ from all lower forms and necessitates the construction of some sort of nest to protect the eggs and retain heat. Next to migration, the highest development of bird instinct is shown in some of their nest construction.



FIG. 100. Nest of humming bird, made of sycamore down. (One-half natural size.) From Kellogg.

We must remember that they have no hands or forelimbs to help, but merely beak and feet, and their materials are only such as they can find. Yet, when the wonderful home of an oriole or humming bird is studied, we realize that even with hands, and brain, and tools, we could not imitate them. Nests differ widely both as to materials and construction. Earth, clay, sticks, grass, hair, feathers, moss, and even strings are some of the substances used, while the structure itself may vary from a mere hole in the sand (ostrich) to the dainty nest of a vireo.

Excavated Nests. Water birds often lay their eggs on rocks, with only sticks enough to keep the eggs from rolling; holes in the ground serve for kingfisher, and bank swallows, while owls and woodpeckers excavate homes in hollow trees.

Woven Nests. Very simple grass nests are made by ducks and wading birds. Among the most remarkable woven nests are the covered pendant homes of orioles and vireos, hanging from slender limbs where no thieving cat or red squirrel can come. Horsehair and plant fibers are used and always seem to be so well

NESTS OF SOME COMMON BIRDS

Name	Nest in or on	Material and description
Kingfisher	Hole in bank	6 to 8 ft. deep; eggs on ground or few feathers
Woodpecker	Holes in trees	Usually cut into hollow tree through side
Crested fly catcher	Holes in trees	Bulky, of grass, etc. May use a snake skin
Robin	On branch or crotch	Bulky, of mud and straw, grass lined, heavy
Passenger pigeon	In trees	Loosely made of sticks
Blue jay	On branches	Bulky, ragged, of twigs, leaves, rags, string, etc.
Crow	In trees	Very bulky, of sticks, cedar bark, sod, hair, etc.
Grebe	In bogs	Decayed damp plants
Red-wing blackbird	In bushes and reeds	Deep, mouth contracted, of grass and rushes
Phoebe	Under bridges or on houses or rocks.	Moss, cemented with mud and lined with hair
Barn swallow	Hollow trees or eaves	Mud and straw, lined with hay or feathers
Chimney swift	Hollow trees or chimneys	Sticks glued with saliva, cup shaped
Whip-poor-will	Dead leaves	No real nest, slight depression
Quail	Underbrush	Arch of vegetation over nest made of grass
Meadow lark	Underbrush	Similar to above, but smaller
Marsh wren	On reeds in swamps	Many dummy nests, made of reeds and grass, down lined
Humming bird	On high branches	Tiny, deep nest, saddled on branch, moss covered
Oriole	Over-hanging branch of elm tree	Pendant, woven of hair, string, and grass
Oven bird	On ground	Bottom compact, sides loose, resembles hornets' nest Under arch of grass, entrance at side

selected and woven that the nest often withstands the storms of several seasons, and is repaired and used again, frequently by the same pair that built it.

Built-up Nests. Robins make a clumsy nest of clay, lined with grass and feathers, placed on the big branches where cats easily reach them. Swallows are much better masons and build clay nests on barns and cliffs, which are very strong and inaccessible. They roll the clay into pellets with the beak and build the walls a little at a time, leaving one layer to dry before adding more, lest it all collapse. The chimney swift (which is not a "swallow" at all) builds a nest of sticks held together by a sticky saliva which hardens into a strong glue. It is used in China to make a sort of edible gelatine; it is from this fact that come the stories of the "edible birds' nests" of that far-off land. These are merely some of the various types of nests. Each species of bird builds its own peculiar structure, always in the same way, of similar materials, and in the same kind of location. Yet there seems to be no way in which one generation is taught to build like its ancestors, and when we say it is due to instinct, we have not explained how they learn to construct such perfectly adapted homes.

Both the nest building and the incubation (sitting) are usually done by the female, though in some species the male helps in both processes. On the other hand the cuckoo avoids either task by laying her eggs in other birds' nests, where the young cuckoos sometimes crowd out their foster brothers.

Eggs. Reproduction in birds is by means of eggs as has been the usual method in all animals previously studied, but the size, structure, and care of birds' eggs place them on a higher plane of development. The development of birds' eggs requires constant warmth. This necessitates the building of a nest and the constant care of the parent, neither of which is usually required in lower animals.

Structure. The egg consists of the actual growing point or germ spot at the upper side of the yolk, the yolk surrounded by the "white," this by a double membrane, and this in turn by the shell. The germ cell is fertilized and from it the chick develops. The

yolk and white both furnish food for the developing embryo, somewhat as does the endosperm of a seed, while the membranes and shell are protective coverings, porous enough to admit air to the chick, and to allow the discharge of carbon dioxide. Fertilization takes place in the ducts leading from the ovaries. Cell division goes on for about twenty-four hours and then ceases, only to recommence in case the egg is warmed and kept at proper temperature.

As the tiny egg germ passes along the oviduct, the yolk and white are added, layer by layer; these layers sometimes separate in a hard boiled egg. The yolk is the real egg, corresponding to that of fish or frog, while the white and shell are added nourishment and protection somewhat like the jelly that coats the frog and toad eggs.

Decay of stored eggs is caused by bacteria that pass through the pores of the shell. If eggs that have no bacteria in them (*i.e.* "fresh") are sealed air-tight by a solution of water glass, they do not decay as no bacteria can get in. If eggs are kept in cold storage, the bacteria, even though present, do not develop and the egg "keeps" for months with but little change.

The shape of most eggs is oval, for two reasons: they pack better together in the nest, and cannot easily be rolled out. Try to roll a bird's egg and it will follow a circle and come back to about where it started. Eggs of birds making deep, safe nests are not so oval, partly because they are safe without this adaptation.

The number of eggs varies with the amount of care that the parent birds can give the young. It is greatest in those kinds, whose young receive the least attention and which try to shift for themselves early in life. This increases their chances of destruction and makes necessary more eggs if any are to survive. In case of birds that are helpless when hatched and are fed and protected by parents, the number is lower. Common wood and field birds average about five, while game and river birds have twelve or more; on the other hand birds of prey produce but one or two.

The size of the egg is greater in those species which hatch well developed, since more stored food is required to carry on the longer

development. In all cases, however, they are large in comparison with eggs of other animals.

The color varies greatly and is probably protective in some cases where nests are open and exposed. On the other hand, eggs laid in burrows and deep dark nests are usually very white, possibly to make them more visible.

Use. Since the egg is practically a store of food for a young animal, it provides an especially nourishing and concentrated form of human food which has been used by man for ages. Eggs require no cooking, are rich in proteid and fat and are practically all digestible. The egg crop of the United States is worth over \$300,000,000 per year.

Incubation. The time of "sitting" or incubation is in proportion to the size of the egg and varies from thirteen to fifteen days for small eggs, to forty or forty-five days in the case of the swan. The female usually sits, but the ostrich is an exception. Some other male birds help in the incubation. The temperature required is 105 degrees and must be kept almost constant. In birds which are helpless and have parental care, the incubation begins as soon as the first egg is laid, and the chicks hatch one after the other, but in those birds like our hens, where the chicks hatch fully feathered and able to feed themselves, all the eggs are laid before sitting begins, so that they may all hatch at once.

Bird Migration. One of the most mysterious and wonderful instincts in the world is that which controls the migration of birds. The causes, methods, and means are little understood. Many birds never migrate, such as the ostrich, fish-eaters, and parrots. Crows, owls, jays, woodpeckers, and many others are practically permanent residents.

Migration may be caused by food supply, climatic changes, or may be made for breeding purposes. It is not easily understood why some species leave abundant food and warmth in the tropics to breed in the cold and barren North. Insect eaters have to migrate as winter kills their prey; water birds must leave their ponds before they freeze over; fruit eaters follow the season of their diet to some extent, but after all, this does not account for the majority of cases.

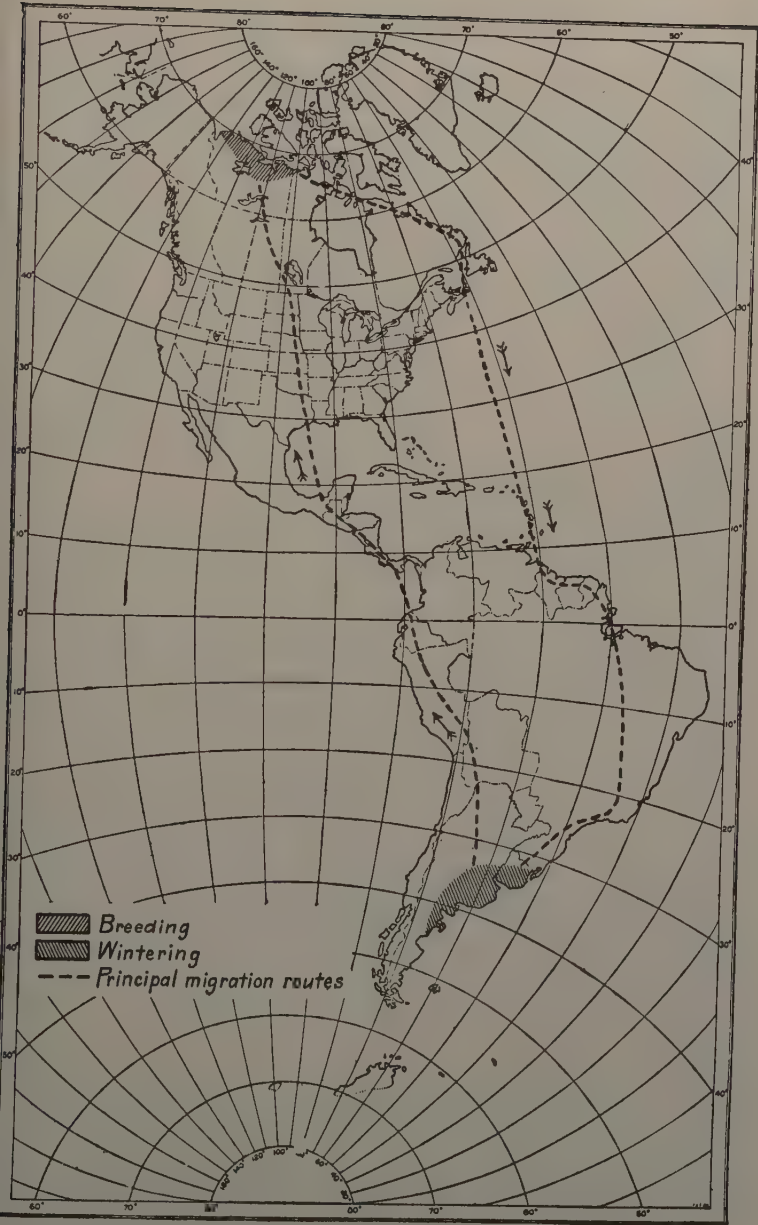


FIG. 101. Distribution and migration of the Eskimo curlew. (From Cooke; *Yearbook, U. S. Department of Agriculture*, 1914, see Pearse.)

Ducks, hawks, swallows, and swifts migrate by night, while warblers, thrushes, orioles, sparrows and shore birds travel by day, thus gaining opportunity for day time feeding, and nights for rest and protection. The distances covered are enormous and could hardly be believed, were they not abundantly verified. Here are some examples of the start and finish of their journeys:

The bobolink travels from New York to Brazil

" black poll warbler	from Alaska to South America	5,000 mi.
" night hawk	" Yukon to Argentina	7,000 "
" shore birds	" Arctic regions to Patagonia	8,000 "
" arctic tern	" Arctic to Antarctic circles	11,000 "

This last is the champion long-distance traveller. They make the *round trip* in twenty weeks.

While many birds migrate slowly, feeding by the way, and averaging only twenty to thirty miles per day, there are others which are marvels of speed and endurance. Bear in mind that it is considered a record performance to drive a car from San Francisco to New York, 2500 miles, in a week and that the trains require about four days. Then look at some of these records.

Gray-cheeked thrush travels from Louisiana to Alaska in thirty days, a distance of 4000 miles.

Golden plover travel from Nova Scotia to South America in forty-eight hours, a distance of 2400 miles. Over the open ocean without chance for rest, this bird uses two ounces of its fat as fuel for the whole 2400 miles. Compare this with the fuel used in the best aeroplanes, which even then have seldom travelled half this distance without stopping. The tiny humming bird has a record of 500 miles per night, across the Gulf of Mexico, and then is not tired enough to rest, but often flies on inland to make a good trip of it.

Routes. Wonderful as are birds' speed and endurance, a real mystery surrounds their knowledge of the times and routes for migration. Similar species follow the same routes year after year, some going direct over the ocean (like many water birds) some follow the West Indies across to South America; many cross the

Name of Bird	Animal Food	Vegetable Food	Rodents, etc.	Possible Harm.
Quail	Potato bugs, etc., 14 %	Weed seed, 63 %		
Wood peckers	Wood borers, ants, 3 to 5000 ants apiece			
Night hawk	Grasshoppers, flying ants			
King bird	Flies, bees, beetles	Wild fruits		
Phoebe	Beetles, spiders, 93 %			
Blue jay	Harmful insects, 19 %	Nuts and acorns	Mice, fish, salamanders	Eats some corn, eggs, young birds
Crow	Grasshoppers, beetles	Corn, wild fruit	Mice	Pulls corn, eats eggs, chicks, frogs
Red-wing	Grasshoppers, weevils	Weed seed, 57 %		Grain, fruit, peas, and corn
Meadow lark	Grasshoppers, etc., 73 %	Weed seed, 12 %		
Grackles	Insects, 35 %	Weed seed, 875 tons per year	Mice and snails	Some fruit, grain
Junco		Weed seed mainly		
Field sparrow	Flies, ants, wasps, enormous numbers	Wild fruit, seeds, 74 %		Cherries, 5 %; cultivated fruit, 13 %
Swallows				Some cultivated fruit
Cedar bird	Insects, 98 %			
Wren	Grasshoppers, 43 %, caterpillars	Wild fruit, 47 %		
Robin	Insects, 76 %	Wild berry seed		
Bluebird				
Horned owl			Rabbits, rats, mice	
Cooper's hawk			Rabbits	Chickens, grouse
Sharp shinned hawk				Chickens, other birds

Gulf of Mexico directly over 500 to 700 miles of open water. Others follow the coasts or river valleys and may even go by one



From American Museum of Natural History.

FIG. 102. The birds carry their plumes only during the nesting season; killing the parents means the slow starvation of the young.

route and return by another. How do they know the way? Keen sight may help, but not over water or through dark nights and fogs. They do not seem to follow water ways or mountain ranges in

many cases. The memory and leadership of old birds, though often helpful, cannot account for migration of young by themselves to lands they have never seen. We have to assume an instinct of migration and a "sense of direction" developed to a degree that we can only imagine, and that is really no explanation at all.

Economic Importance of Birds. There is no group of animals to which man is more indebted than the birds. It is highly probable that without their aid, agriculture would be impossible, because of the vast quantity of insect pests and weed seeds which they destroy. The accompanying table shows the nature of the food which they eat, and it is well to remember that they eat early and often.

Their greatest service is in the destruction of harmful insects both as egg, larva, and adult. In some states where general bird killing was permitted the insect enemies of crops increased to such an alarming extent that stringent laws were put in force.

An unwise bird law cost the state of Pennsylvania nearly four million dollars in a year and a half through the destruction which it permitted among useful birds. At the end of this period, the damage was so apparent that they repealed the law and appointed a state ornithologist to look after the birds. Actual experiments have been worked out with protected and unprotected bird regions so that the fact of their essential service can no longer be questioned.

Next to their destruction of harmful insects comes their work against the seeds of weeds which, as the table shows, constitute a large part of their diet. Many of the larger birds, such as hawks, owls, and jays, destroy mice, rats, and other harmful vermin. Some, like the crow, vulture, and buzzard, act as scavengers.

Almost as important are the products which man obtains from the birds. Our domestic fowls produce flesh and eggs to the amount of over half a billion dollars annually. This does not include the value of game or wild birds. Feathers for millinery and bedding are another valuable bird product, and where the feathers are those of food birds, it is a perfectly legitimate one. In some Pacific islands, where millions of sea birds have roosted for centuries,

vast deposits of manure, called guano, have accumulated, which are very valuable for fertilizer.

A curious and rather pitiful use for birds is to detect poisonous gases in mines and in warfare. Their rapid respiration and delicate nervous system make them more sensitive than man to the presence of dangerous gases. They are taken in cages into the mines or trenches where their symptoms of suffocation give warning in time for the men to take precautions.

Another very specialized use for birds, which the war has greatly developed, is the carrying of messages by pigeons, carefully trained to return to their homes, when carried to the front and liberated. Often they have been able to bring back messages through shell fire where no man could live.

Last, but by no means least, is the value of birds to man as companions and pets. If the world were deprived of all bird song and color, it would be a dreary place, and even those who now overlook them, would miss their accustomed presence.

There is no large group of animals with so few harmful members. The food table indicates a few which destroy fowls or useful birds and a few others that eat grains and useful fruits. Another class of damage is in cases like that of the English sparrow and starling where a foreign bird is interfering with our native species. The accompanying "Black List" includes all having even a suspicion against them, and shows how few there are, which do any harm at all.

<i>Positively harmful</i>	<i>Possibly harmful</i>
Cooper's Hawk	Blue Heron
Sharp Shinned Hawk	King Fisher
Pigeon Hawk	Crow
Great Horned Owl	Blue Jay
Snowy Owl	Grackle
English Sparrow	Cow Bird

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Wright, pp. 63-72; *News from the Birds*, Keyser, pp. 139-149; *Wake Robin*, Burroughs, pp. 1-35; *Bird Migration*, Cooke, U. S. Bulletin 185, entire; see also magazine references; see also in Encyclopedia, under "Migration," "Nidification," "Egg."

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Nesting and Eggs: *Bird Homes*, Dugmore, pp. 11-15; *Our Native Birds*, Lange, pp. 33-41; *Bird Life*, Chapman, pp. 64-70; *Citizen Bird*, Wright, pp. 73-86; *News from the Birds*, Keyser, pp. 37-49; *Birds of Field and Village*, Merriam, see index; *Animal Life*, Kellogg, pp. 264-268; *Animal Life*, Thompson, pp. 114-115, 264-267.

SUMMARY

Foods used.

Animal.

Rats, mice, rabbits, etc.

Fish

Scavengers

Insects on the wing.

Insects under bark

Insects on the ground

Insects on plants

Vegetable.

Weed seeds

Grains (rice)

Fruits

General value of birds.

Harmful exceptions.

Cooper's and sharp-shinned hawks, great horned owl, English sparrow, and starling (why so numerous?).

Hawks, owls, birds of prey.

Loon, pelican, kingfisher.

Vulture, buzzard.

Swifts, night-hawks.

Woodpecker.

Robins.

Warblers, vireos.

Sparrows, etc.

Blackbirds, bobolink.

Wax wing, blackbird.

Nest Building.

Necessity for nest, warmth for egg and protection of young.

Kinds.

Excavated in earth	Kingfisher, bank swallow.
Excavated in trees	Woodpecker, owl.
Woven cup shaped	Warblers.
Woven hanging	Orioles, vireos.
Built up of clay	Robin, eave swallow.
Built up of sticks	Chimney swift (not swallow).

Eggs (cf. other forms of eggs as to size, covering, fertilization).

Structure.

Germ spot	develops embryo.
Yolk	for nourishment.
White	for nourishment.
Membranes	Protection, admit air, exit CO ₂ .
Limy shell	Protection, admit air, exit CO ₂ .

Causes of decay and means of prevention.

Shape, "oval" for better fitting, will not roll.

Number, fewer where more parental care and young helpless.

Larger where young are precocial, average five.

Size, larger where chick hatches well developed.

Color, protective, white in dark nests.

Use as food for man.

Concentrated, need no cooking, all digestible.

Incubation.

Small eggs less time (13-15 days), larger 40-50 days.

Female usually "sits."

Chicks hatch in series in altricial birds.

Chicks hatch all at once in precocial birds (why?).

Migration.

Causes, food scarcity, climatic changes, breeding.

Methods, night fliers; ducks, hawks, swallows, etc.

Day fliers; shore birds, warblers, thrushes.

Distances, from five to eleven thousand miles.

Travel in flocks for protection and direction.

Routes, rather definite, along coasts, mountain ranges, etc.

Not known how they direct themselves.

Examples of above instances.

Economic Importance.

1. Destroyers of harmful insects.
2. Destroyers of weed seeds.
3. Destroyers of harmful rodents and other vermin.
4. Scavengers.
5. Producers of food, flesh and eggs.
6. Producers of feathers, bedding, and millinery.
7. Guano for fertilizer.
8. To detect poisonous gases.
9. To carry messages.
10. To furnish enjoyment by their beauty and songs.
11. A few destroy useful birds or other animals.
12. Some destroy fruit or grain.
13. Some interfere with nesting of other birds.

For harmful species, see "Black List of Birds."

CHAPTER XXXIII

MAMMALS

Vocabulary

Ruminant, animals adapted for re-chewing their food.

Vertical, straight up and down.

Quadrupeds, four-footed animals.

The mammals constitute the highest group of the animal kingdom because in them the development of the brain, intelligence, and reason have reached the highest degree of specialization.

The birds excelled in adaptations for flight and in marvelous instincts for nest-building and migration. The communal insects have carried division of labor to a remarkable perfection, but if we compare the real intelligence of these forms with that displayed by a dog, a beaver, or a horse, not to mention man, we can see that there is no question as to the mammal's position at the top.

Mammals include man, the apes, quadrupeds, bats, seals, whales, etc., and are a very diverse group as the tabulation shows. They vary in size from the tiny harvest mouse that can climb a wheat stem, to the enormous whale, a hundred feet in length. They are found in all parts of the world except on a few small Pacific islands and are the group of animals with which man (himself a mammal) has had most to do.

The chief characteristics of this important class are as follows:

1. The young are born alive (no external eggs).
2. The young are nourished with milk.
3. The body is more or less covered with hair.
4. The cerebrum is highly developed.
5. A diaphragm (breathing muscle) is present.
6. They have two sets of teeth and fleshy lips.
7. High circulatory development, left aorta only.

Various Adaptations. Mammals include about 2500 different species, which, compared with insects is a small number, yet their habitat and mode of life varies so widely that they are a splendid illustration of the modification of homologous parts for different functions.

Limbs. All mammals have two pairs of limbs, usually provided with five toes; some are modified for flight (bats), some for swimming (seals, whales), some for rapid land locomotion (horse, deer), some for climbing (squirrel), or for burrowing (mole), for attack and defense (cat, tiger), for jumping (kangaroo), for prehension (apes, man).

Teeth. In the same way the teeth may vary in structure and use, there being usually four kinds present, the incisors, canines, premolars, and molars. In some animals they are adapted for tearing prey (tiger, lion), some for gnawing (rat, beaver), some for grinding vegetable foods (horse, cow). All are of similar origin and are merely different forms of the same organs.

Body Covering. The body covering also varies greatly. The hairs of the dog or horse, the wool of the sheep, the quills of the porcupine and the scales of the armadillo, are all of similar origin. Claws, hoofs and nails, horns, bristles, manes and tails are also developed from epidermal structures.

Four Important Orders. The mammals of North America represent eight orders out of eleven, the three remaining orders being found in Australia or the tropics. From this number we shall study only four, the rodents, ungulates, carnivora, and primates.

The Rodents (gnawers) include many of our commonest animals, the rabbits, porcupines, guinea-pigs, chipmunks, squirrels, beavers, rats, mice, and woodchucks. All these forms have teeth especially adapted for gnawing: the front teeth (incisors) are chisel shaped, strong, and provided with a continuously growing root, so that they replace themselves as fast as they wear off. Also the front edge is harder than the rear edge, so that they are self sharpening since the cutting edge is always worn thin. These tooth adaptations together with strong jaws and powerful jaw muscles fit the

rodents for their well-known occupation of gnawing their way through life.

The Ungulates (hoofed animals) include some of our commonest domestic animals, such as the horse, pig, cow, sheep, and goat. Among its familiar wild members are the deer, antelope, tapir, rhinoceros, hippopotamus, giraffe, camel, zebra, etc. All of these most of us have seen in circuses and zoölogical gardens. These animals live on vegetable foods and have back teeth (molars) fitted for grinding. Most of them have a side-wise jaw motion which also aids in this process. Their feet are encased in hoofs, and the limbs are never used for prehension, being adapted only for swift locomotion. There are never more than four toes in use and frequently fewer are developed.

The Ungulates are divided into two groups:

1. *Odd toed* in which the weight is borne on one toe though others may be present. They include the horse, rhinoceros, and tapir.

2. *Even toed* in which the third and fourth toes bear the weight, though two others are usually present.

These even-toed ungulates are again divided into two groups called

1. The non-ruminants (pig, hippopotamus).
2. The ruminants (cow, sheep, deer, etc.).

The ruminants are so called from their habit of chewing their food as a "cud." A cow, for example, first compresses its food into a ball, swallows it into the first of the divisions of its four-chambered stomach where it is stored. Later it is forced back into the mouth, chewed thoroughly and swallowed again, but into another stomach chamber, where the final processes of digestion are completed. The advantage of this peculiar arrangement is that much food can be hastily eaten and stored, to be chewed later. This, for an animal which feeds in flocks, on bulky vegetable food is of great importance, since it can get its share in haste and chew it at leisure. The ungulates include most of our domestic animals. From them we obtain the bulk of our animal food and clothing, leather, horn, and other products and among them we find nearly

all our beasts of burden. It would be almost impossible for man to exist without this important group of animals.

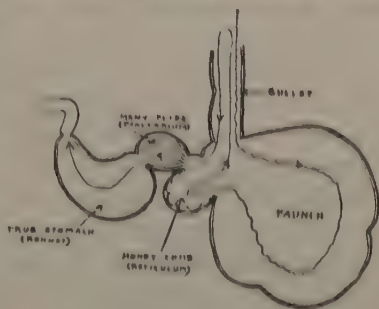
The Carnivora (flesh eaters) are very highly specialized in structure for the pursuit of prey, and in fact, live largely upon the ungulates whose adaptations have been along the line of keen senses and swiftness to escape this very danger. The carnivora have large, interlocking canine teeth, shear cutting molars, a very strong jaw hinge, and enormous muscles attached to ridges on the skull. Their skeleton is light and slender, the jaw short and strong, and the feet usually provided with claws. These claws, in the cat family, can be withdrawn into sheaths, which keeps them sharp and also permits a noiseless approach upon their prey.

On the other hand, the dog family cannot withdraw the claws, which are therefore blunt and not used for prehension, but for swiftness of chase, which is characteristic of their manner of hunting. Their keenness of sight and smell have been especially adapted for their manner of life.

The carnivora include two divisions: (1) the aquatic forms (seal, sea lion, walrus) in which the limbs are short and web footed; (2) the land forms with long limbs and separate toes. These land forms are divided into three groups, according to the manner of walking:

1. Those walking *flat* on the foot (bear, raccoon).
2. Those walking on the *toes only* (dog, wolf, fox, hyena, cat, tiger, lion, leopard, etc.).
3. Those walking *partly* on the toes (martin, mink, weasel, otter, sable, skunk, etc.).

It will be noticed that, except for the dog and cat, none of the carnivora are domestic animals, and few of them are used as food,



STOMACH OF A RUMINANT.

FIG. 103. After Wiedersheim.

while, on the other hand, most of our valuable furs are produced by them.

The Primates. This group includes the highest of the mammals, and comprises the monkeys, gorilla, chimpanzee, orang-utan, gibbon, marmoset, and lemur, as well as man himself.

Their structural adaptations do not compare with those found in many other orders, but the greater brain development and intelligence places the primates at the head of the classification.

This brings up again the fact that brain development is the only way in which man may hope to excel. He belongs to what is called a "generalized order" of animals; that is, he is not structurally adapted for any particular thing, such as flight, speed, strength, swimming, etc., his only claim to distinction being along the line of intellectual development.

There is nothing that man can do, *if unaided by his intelligence* which many other animals cannot do much better; but when this intelligence is at hand to direct him, there is no other animal that can compete with him.

Structurally, man resembles the higher apes very closely. Almost every detail of their anatomy is similar — skeleton, muscles, teeth, position of eyes, structure of the hand, and even motions and facial expressions. There are, however, certain structural differences such as the more erect position, shorter arms, larger and better-balanced skull, higher forehead, smaller canine teeth, and his inability to use the big toe like a thumb for grasping.

These differences are utterly unimportant when compared with the one great feature, the human brain. The brain of all the primates is large but man's is one-third larger than the chimpanzee's which most nearly approaches it in size.

Man has learned the use of tools, devised a spoken and written language, found a means of controlling fire, and developed mental faculties and social habits that place him in a position far above the highest apes.

It is curious to note how three factors have contributed to man's development. The erect attitude left the fore limbs free from use in locomotion and permitted their development into the most

wonderful organ of prehension in the world, the hand, which is man's one point of high structural adaptation.

It is difficult to say whether the brain taught the hand, or the hand helped develop the brain, but it is certain that these three factors, erect position, hand, and brain, have been the essential ones in man's development.

There is more *structural* difference between the lowest primates (lemur) and the chimpanzee or gorilla, than there is between these higher apes and man. Also there is a greater difference between the lowest type of savage man and the highest type of civilized man, than there is between the savage and the ape.

Results of Erect Posture. As a consequence of his erect posture, man's hands are left free for use in grasping things. However, nature does not give something for nothing, and man has to pay for his upright position by certain disadvantages. In the first place, since only one pair of limbs are used in locomotion, he must balance upon two feet instead of four, and has the center of weight high above the point of support. This necessitates the long and difficult process of "learning to walk" which other animals do not experience.

Placing the weight vertically on the hips instead of at right angles to them, renders man more liable to hip, spinal, and foot, diseases and deformities. The internal organs rest one upon another in a vertical pile instead of lying side by side, producing a tendency to pressure or displacement. When sick or tired we instinctively lie down to relieve this strain.

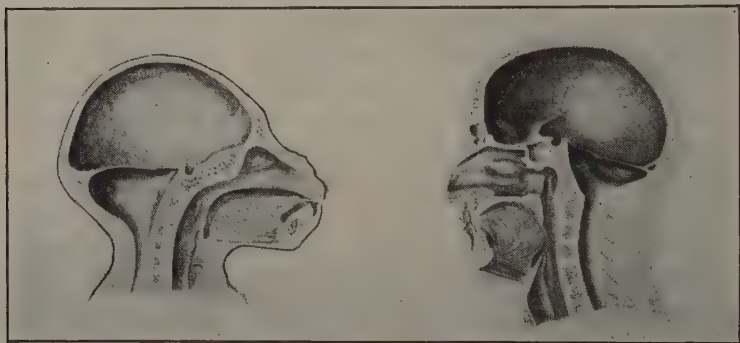
The arteries of the arm-pit, neck, and groin are now exposed toward the front, whereas in quadrupeds they face downward and are protected. In man, the trachea and appendix open upward, instead of forward, giving opportunity for the entrance of irritating substances.

All these difficulties, which are the price of our erect posture, are more than repaid by the advantage of the human hand and the mental and social development which it has made possible.

It rests with the intelligence of man to overcome the natural difficulties of his structure by especial attention to correct posture,

position of spinal column, and support for the arches of the feet. The strain on the internal organs can be met by training the abdominal muscles to support their extra burden, and by proper exercise and breathing. All this is but a small price to pay for the human hand.

Relationship. Contrary to the ideas of some ill-informed people, no scientist has ever claimed that man is "descended from" an ape or any similar form, neither is there any "missing link" to be discovered. On the other hand scientists *do* agree that both man



From American Museum of Natural History.

FIG. 104. Brain case and face in ape and man. In the ape (young gorilla, at the left) the brain case is comparatively low, and the face is shallow; in man (adult white man, at the right) the brain case and the face are both very deep; the face has been retracted beneath the brain case. *Figure after Ruge.*

and the apes are descended from a common ancestor from which both lines have developed. This accounts for the very great similarity in structure. In the same way, we resemble our cousins though we are not descended *from* them, but are related by way of a common ancestor, or grandparent.

Aside from man, the primates include:

1. The gorilla, the largest of the apes, a native of Africa. It is erect, does not climb trees, and resembles man closely in structure, though much stronger.

2. The chimpanzee, also found in Africa. Though smaller than

CLASSIFICATION OF MAMMALS

Order	Characteristics	Representatives
Primates Carnivora Aquatic Land Ungulates Odd toed Even toed	High intelligence, man like Flesh eaters Limbs modified to flippers Walk on clawed toes Walk on flat foot Hoofed, vegetarians One or three toes mostly used Two toes mostly used, four present Non-ruminant Ruminant	Man, apes Seal, walrus Cat, dog, lion, wolf Bear, raccoon Tapir, horse, rhinoceros
Proboscidea Sirenia Cetacea Chiroptera Insectivora Rodents Edentates Marsupials Monotremes	Tusks from incisors, trunk Aquatic, conspicuous neck Aquatic, no neck, fin-like limbs Wing membrane on four fingers Burrowing insect eaters Gnawers, sharp incisors Teeth few or none Abdominal pouch for young Have beak, reproduce by eggs	Pig, hippopotamus Cow, deer, sheep Elephants Sea-cows Whale, porpoise, dolphin Bats Mole, shrew Rat, rabbit, beaver Sloth, armadillo Opossum, kangaroo Australian duck-bill

man, it resembles him more closely than the gorilla, in brain, face, hands and ears.

3. The orang-utan, found in the East Indies, which also resembles man in brain structure and skeleton.

4. The Old World monkeys and baboons (Asia-Africa), which have narrow noses and long prehensile tails.

5. The New World monkeys (South America), with wide flat noses and prehensile tails.

6. Marmosets (Mexico, Brazil), lemurs, (Madagascar), small forms, not at all like man in structure.

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UNGULATES

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PRIMATES

The Life of Animals, Ingersoll, pp. 7-57; *Riverside Natural History*, pp. 480-500; *American Natural History*, Hornaday, Chap. II; *Animal Life*, Thompson, pp. 340-350; *Types of Animal Life*, Mivart, pp. 1-35; *Winners in Life's Race*, Buckley, pp. 240-255, 333-353.

SUMMARY

Mammals excel in intelligence.

Birds excel in instinct and flight adaptations.

Insects excel in "division of labor" in communal forms.

Mammals vary in size from mouse to whale.

Mammals vary in distribution, relatively few in number (2500).

Characteristics.

- | | |
|--|-------------------|
| 1. Living young, egg matures internally. | 4. High cerebrum. |
| 2. Young nourished with milk. | 5. Diaphragm. |
| 3. Hair. Fleshy lips. | 6. Two sets teeth |
| 7. High circulation, left aorta. | |

Modifications of limbs (two pairs, five toed).

Adapted for

Examples

Swimming

Whale, seal

Flight

Bats

Land locomotion

Horse, deer

Climbing

Squirrel

Burrowing

Mole

Fighting

Cat, tiger, etc.

Jumping,

Kangaroo

Prehension

Man

Modification of teeth (incisors, canines, pre-molar, and molars,).

Catching prey

Lion, tiger, cat

Gnawing

Beaver, rat, mouse

Grinding

Horse, cow

Tusks

Elephant

Modifications of body covering.

Hair

Dog, horse, man

Wool

Sheep

Quills

Hedgehog, porcupine

Scales

Armadillo

Claws, hoofs, bristles, tails, manes, etc., are other forms.

Rodents.

Representatives.

Adaptations.

Teeth for gnawing (incisors).

1. Chisel shape, self-sharpening.
2. Strong, powerful jaws and muscles.
3. Continuous growth (why?).
4. No canines.

Ungulates.

Characteristics, hoofed, vegetable food, large size.

Limbs for locomotion *only*.

Not more than four toes.

Odd toed, horse, rhinoceros, tapir:

Even toed.

Non-ruminant, pig, hippopotamus.

Ruminant, cow, bison, sheep, goat (hollow permanent horns), deer, elk, moose (solid, shed horns).

Characteristics of ruminant stomach.

Reason for ruminant habit.

Value to man.

Food, meat, and milk, with all related products.

Wool, leather, horn, etc.

Transportation, horse, ox, camel, mule, llama, etc.

Carnivora.

Specialized for pursuit (ungulates for escape).

Characteristics.

Small incisors, interlocking canines, shear molars.

Strong jaws, jaw muscles, and immovable hinge.

Light strong body, keen senses, claws.

Aquatic forms (short limbs, webbed toes), seal, walrus, etc.

Land forms (long limbs, separate toes).

Plantigrade, bear, raccoon.

Intermediate, mink, weasel, otter, skunk.

Digitigrade (claws not retractile), dog, wolf, fox.

Digitigrade (claws retractile), cat, lion, tiger, etc.

Value to man.

Few for food, many for furs, aid in chase, enemies.

Primates.

Representatives, gorilla, chimpanzee, orang-utan, monkeys, gibbons, lemurs, man.

Characteristics.

Generalized structure (meaning). Higher brain.

Man resembles other primates in

Skeleton, muscles, teeth, eyes, hand, habits.

Man differs from other primates in

Erect position, shorter arms, balanced head, forehead.

Smaller canines, non-opposable toe.

Brain and intelligence which results in

Tool using, fire control, language.

Social and moral development, mind, reason.

Factors in man's development.

Erect attitude, and its consequences.

Hand free for prehension.

Brain development resulting as above.

Relationship of man and other primates via a common ancestry, not by "missing links."

(See Hornaday for pictures of all mammals, especially primates.)

CHAPTER XXXIV

THE DEVELOPMENT OF MAN

Vocabulary

Unwarranted, uncalled-for.

Rudimentary, undeveloped traces of organs.

Fossil, remains of former plants or animals, embedded in rocks.

Evolution, gradual development, from simple to complex.

With an egotism which is entirely unwarranted, we are accustomed to speak of "man and animals" whereas we ought to say "man and *other* animals," for certainly man is an animal just as truly as the beast of the field.

By referring to the characteristics given in preceding chapters, man's place in the zoölogical scale will be seen to be as follows:

Kingdom: animal.

Branch: vertebrate.

Class: mammals.

Order: primates.

The Idea of Evolution. As soon as man became intelligent enough to make comparisons between himself and other animals, the resemblances became apparent and led to the idea that some relationship must exist with lower forms. Two thousand years ago the Greeks discussed this fact and advanced various theories to account for it.

Very gradually, information accumulated, and the idea of relationship developed into the theory that not only man but all living things, both plant and animal, are not only related, but actually descended from common ancestors. This is called the theory of descent, or *evolution*.

Evidences of Evolution. 1. *Rudimentary Organs.* Not only do all animals resemble each other in general ways, but many forms

possess organs which are of no use to them, but are developed in other groups for important functions.

For example, in the foot of the horse there are unused bones which in other animals support separate toes. The ostrich has small wings like those of other birds, but it cannot use them for flight. The boa constrictor has remnants of a hip girdle though it has never developed legs to use it.

In man there are about seventy such structures, well developed in other animals but reduced in size and function in his body, like remains of the scaffolding of construction left in a completed building and showing thereby the process of its development. Among these may be mentioned the appendix which in the rodents is the largest part of the intestine, while in man it is reduced to a small and apparently useless rudiment. Similarly we have small canine teeth, but do not develop them to tear food like the dog; we have an inturned ear tip and muscles to *move* it, but we do not "prick up our ears" like a horse.

The list might be greatly extended, but the point is this, — if animals and plants are not developed from common ancestors, why then do they have these resemblances in structure.

2. *Embryological Resemblances.* In the study of the development of the embryos of all animals, it is found that the higher forms pass through stages resembling lower types, as they develop.

The first stage of all plants and animals is the single fertilized egg cell. In all cases this develops by almost identical steps, into (a) a solid mass of cells, (b) a hollow sphere of cells, (c) an infolded tubular form, and then up through more and more specialized structures to the adult, whatever it may be. The early forms of all vertebrate embryos are so similar that dog, cat, rabbit, or man cannot easily be distinguished until well started toward adult form.

By watching embryonic development of the vertebrates we can observe modifications of various structures, such as the gill arches, which are present in all the early stages. These gradually develop true gills in the fish, but become modified and reduced in the higher forms, their rudiments appearing in man as parts of the inner ear, lower jaw, and throat cartilages. Certainly, if animals

were not related, they would not repeat the structure of lower types as they develop into their final form.

3. *Homologous Organs.* In both plants and animals we find parts, evidently of similar origin and structure, developed for very different purposes.

1. Leaves are modified into petals or thorns.

2. Roots act as organs for climbing or storage.

3. Hoofs, nails, and claws are all of similar origin.

4. Scales, feathers, and hair are all modified forms of the same epidermal structures.

5. The various appendages of crayfish and its relatives are evidently of similar structure, but modified to perform many functions.

Surely this modification of similar parts for different uses would not be found if there were no relationship between the different forms.

4. *Geological Evidence.* Although the fossil remains are necessarily incomplete, still there have been found many series showing gradual development from primitive to present forms. This is notably true of the horse whose ancestors have been traced in fossil skeletons back to a small five-toed form unlike any living representatives. Also in the case of birds and reptiles, remains have been discovered, showing plainly their descent from a common ancestor.

5. *Domesticated Animals and Plants.* We are continually witnessing the development of different forms of plants and animals in our methods of breeding, in which there is no question of relationship of the new form to the old.

Our many kinds of dog are descendants from the domesticated wolf; the different breeds of hogs from the wild boar; fowls, pigeons, sheep, and cattle, with their numerous breeds and races, have been developed purposely by man, from very different ancestors.

From masses of such evidence, laboriously collected, all scientists are agreed that all living things are related, the closeness being indicated by the degree of similarity. They also agree that descent

has not been in a continuous straight line, like the steps upward in a ladder, but that relationship is through common ancestors.

We have certain "family resemblances" to our cousins but we are not descended *from* them; rather, we resemble them because

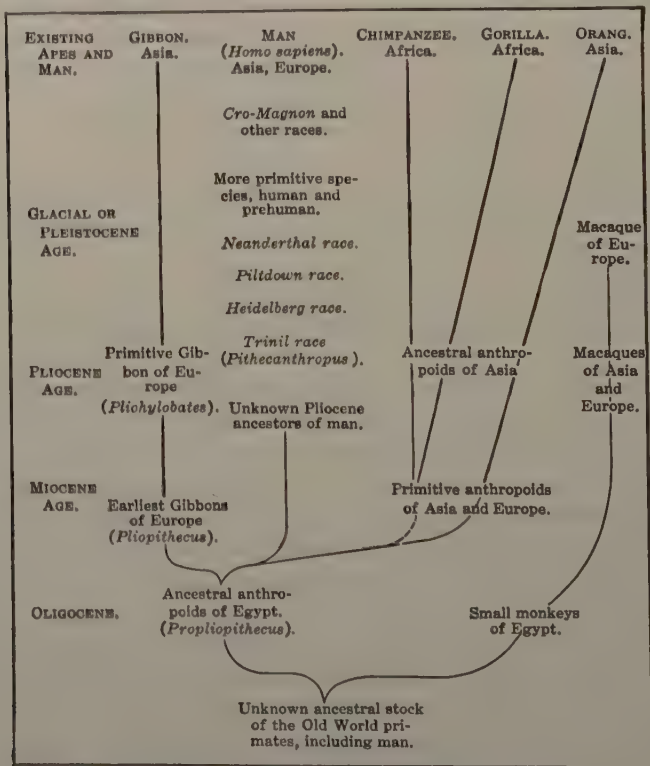


FIG. 105. Ancestral tree of the anthropoid apes and of man. (From Osborn's *Men of the Old Stone Age*. By special permission of the publishers, Charles Scribner's Sons.)

of our common ancestors (grandparents), who contributed to the inherited characteristics both of ourselves and them.

Proof of the *fact* of descent and evolution is only half of the battle; it remains to be shown *how* nature has brought about the

great modifications which have resulted in producing the innumerable forms of living things which inhabit the globe.

COLLATERAL READING

Primer of Evolution, Clodd, Chap. IX-X; *Origin of Species*, Darwin, Chap. 14-15; *Descent of Man*, Darwin, Chap. 1-7; *The Whence and Whither of Man*, Tyler, pp. 1-112; *Applied Biology*, Bigelow, pp. 561-573; *Ascent of Man*, Drummond, pp. 59-98; *Animal Life*, Thompson, pp. 273-281.

SUMMARY

1. Relation to other animals.
Classification, look up characteristics of each group.
2. The idea of evolution.
3. Evidences of evolution.
 - (1) Rudimentary organs.
 - Toe bones of horse.
 - Wing of ostrich.
 - Hip bones in boa.
 - Appendix, canines, etc., in man.
 - (2) Embryological resemblances.
 - Beginning with one-celled egg.
 - Similar early stages.
 - Modification of organs.
 - (3) Homologous organs.
 - (4) Fossil remains.
 - (5) Changes due to domestication and breeding.

CHAPTER XXXV

THE METHOD OF EVOLUTION

Vocabulary

Isolation, separation.

Contemporary, one who lives at the same time.

Divergence, separation of lines of descent.

Predecessor, one who comes before.

Proof of the *fact* of similarity between the various forms of living things, and of their very evident relationship, still leaves a more difficult question to be answered. *How* did this descent and modification take place, by what means has nature developed one form from another?

The idea of evolution of living forms from previous simpler ones had been in existence for centuries, but the first serious attempt to explain the means by which the new forms evolved, was made by Lamarck in 1809. He advanced the view that new species arose by inheriting the results of use or disuse of organs. For example, the giraffe, by constantly reaching for the leaves of trees, developed its neck, and the offspring increasingly inherited the characteristic until a new species was formed.

The time was not ripe for acceptance of Lamarck's ideas; moreover, his theory was not in accordance with facts and was forgotten for fifty years.

Darwin's Theory of Natural Selection. The date, 1859, marks an epoch in biological thought and should never be forgotten. In that year Charles Darwin, an English scientist, published his "Origin of Species by Natural Selection" and established the theory of evolution on a firm basis.

This theory is the corner stone of all recent science and the foundation of all modern thought. It is not confined to biology

alone, but has influenced almost every branch of science. In its broader features it is accepted by every biologist, although there are many details still to be worked out.

Following is an outline of the chief factors assigned by Darwin to account for the development of new species from common ancestry.

1. Over-production of individuals.
2. Struggle for existence.
3. Variation among individuals.
4. Survival of the fittest.
5. Inheritance of favorable characteristics.
6. New forms better adapted to survive are thus "naturally selected" as new species.

Darwin spent over twenty years of strenuous toil and study, accumulating facts upon which to base his theory. Many able men have since devoted their lives to the same end, but we can here only briefly review the argument, following the outline given above.

Over Production. A fern plant may produce fifty million spores per year. If all matured they would completely cover North America the second year. A mustard plant produces 730,000 seeds annually, which if all matured, would occupy two thousand times all the land surface of the earth, in two years. The common dandelion would accomplish the same in about ten years.

The English sparrow lays six eggs at a time and breeds four times a year; if all survived there would be no room for any other birds in the course of a decade. The codfish produces over a million eggs per year; if all survived this would fill the Atlantic solidly with fish, in about five years.

Most amazing of all is the rapidity of reproduction in bacteria and protozoa. One of the latter, if it reproduced unchecked, would make a solid mass of these microscopic animals as large as the sun, in thirty-eight days.

Struggle for Existence. We know there is no such actual increase; in fact the number of various forms changes but little

In other words only a very small minority of these countless hosts reach maturity. All cannot obtain either space or food to live. Thus it is evident that only those best fitted for their surroundings will survive, and the less fit will perish in the struggle.

Variation. It is a well-known fact that no two individuals of any plant or animal are exactly alike; slight variations in structure occur in all. This furnishes the material for nature to use in her selection, and those forms, whose variations tend to adapt them best to their environment, will survive while others perish.

Survival of the Fittest. This expression was first used by another noted English scientist, Herbert Spencer, and almost explains itself. If among the thousands of dandelion seeds produced, some have better dispersal devices, these will scatter to better soil, be less crowded, and so will survive, while those having poorer adaptations will perish by over crowding. In so severe a struggle where only a few out of millions may hope to live, very slight variations in speed, or sense, or protection may turn the scale in favor of the better-fitted individual. Any unfavorable variations would surely be wiped out.

Inheritance. It is common knowledge that in general, the offspring resemble the parents. If the parents have reached maturity because of special fitness, those of their descendants which most inherit the favorable variation, will in turn, be automatically selected by nature to continue the race.

New and Better Adapted Species. A continuation of this process of natural selection will in time produce such differences in structure and habit that the resulting forms must be regarded as new species, genera, and finally higher groups. This process is aided when the developing species are separated by distance, mountain ranges, bodies of water, or climatic differences, so that they do not lose their favorable variations by inter-breeding. This is the theory of geographic isolation which was developed by Alfred Russell Wallace, another English contemporary of Mr. Darwin.

Conclusions from the Theory. 1. *Cause of Adaptations.* It will be seen that natural selection is constantly tending to fit the individual more closely to its environment and thus accounts for

the marvelous adaptations of structure which we always find in all living things.

2. *Relationship of all Forms.* Carrying the theory to its logical conclusion it follows that all the species now on earth, or which have lived there in the past, are descended from a few primitive original forms. The further back the variation began, the greater will be the difference between the present forms, and the more distant will be their relationship. Those more closely allied have separated from a common ancestor in more recent times.

3. "*Tree*" *Lines of Descent.* Evidently our idea of the lines of relationship and descent must be expressed in the figure of a tree, whose main branches separated from the parent trunk early in development and whose topmost twigs represent the present living forms. These will be similar or different, depending on how far back the divergence began.

4. *Classification.* Evolution provides for a natural method of classification, now universally used, in which relationship and descent are shown by the groups in which individuals are placed.

Thus members of a species are more closely related than those of a genus or order. A class includes forms which began to diverge further back than the members of a family. When we speak of any forms as "belonging to the same order" or genus, we are really expressing not only their likeness in structure, but the reason for it, namely blood relationship and descent from common ancestry.

5. *The Key to other Biologic Puzzles.* Evolution accounts for many facts otherwise unexplained. It tells us why we find fossil remains of simpler animals in older rocks, and of more highly specialized forms in later formations. It accounts for the facts of embryology mentioned in the previous chapter, such as the occurrence of primitive structures in the embryos of higher forms, which disappear before maturity. It explains the peculiarities of geographic distribution of animals and plants, in accordance with what we know of past and present relations of land and sea areas.

Some Things that Evolution does Not Teach. 1. That living or extinct forms can be arranged in a straight line of descent, each descended from its predecessor.

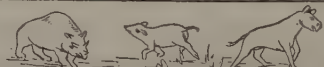
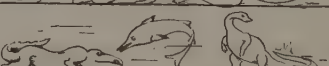
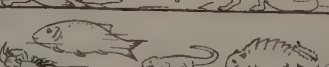
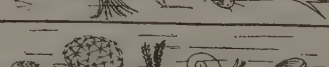
Geological History				
Age	Period	Characteristic Animals		First Occurrence of
Quaternary	Recent			Man
	Pleistocene			Mammoth, Horse, Glyphodonts, Man
Tertiary	Pliocene			Deer Sloths, Ape, Man, Dog, Stag, Camel, Ape, Man?
	Miocene			Elephant, Sabre-tooth, Tiger, Monkey, Cat, Bear, Monkey, Cow, Deer.
	Oligocene			Hoofed mammals, Horse (3 toes), Rhinoceros, Pike
	Eocene			Mammals, Birds, Snake, Lemur, Bat, Hog, Horse.
Mesozoic	Cretaceous			Mammals, Birds, Reptiles, Marsupials, Salamanders.
	Jurassic			Reptiles, Bird, Crocodile, Frog.
	Triassic			Reptiles, Amphibians, Mammals, Turtles, Dinosaurs.
Palaeozoic	Permian			Reptiles, Amphibians, Fishes, Reptiles
	Carboniferous			Amphibians, Fishes, Amphibians, Insects.
	Devonian			Fishes, Ostracoderms, Myriapods
	Silurian			Invertebrates, Fishes, Scorpions
	Ordovician			Invertebrates, Bryozoans, Echinoids, Ophiuroids.
	Cambrian			Crustaceans, Molluscs, Worms, etc., Brachiopods, Trilobites, Molluscs, etc.
Metamorphosed rocks - no fossils				

FIG. 106. From Pearse.

2. That "man is descended from a monkey."

3. That God can be left out of the scheme of Creation. Much opposition was made to Darwin's work on this score, by people who purposely or through ignorance, misinterpreted his conclusions. While we cannot go into the argument here, rest assured that in the minds of the greatest scientists and philosophers there is no conflict between the conclusions of Science and Religion.

To quote Davenport "The Creator is still at work, and not only the forces of Nature, but man himself, works with God in still further improving the earth and the living things which it supports."

COLLATERAL READING

Origin of Species, Darwin; *Descent of Man*, Darwin; *Primer of Evolution*, Clodd, entire; *Evolution*, Thompson and Geddes, entire; *Story of Primitive Man*, Clodd, entire; *Evolution*, Coulter, entire; *Ascent of Man*, Drummond, pp. 1-98; *Whence and Whither of Man*, Tyler, pp. 1-112; *Winners in Life's Race*, Buckley, pp. 333-353; *General Biology*, Needham, Chap. III; *Animal Life*, Thompson, pp. 273-339; *Applied Biology*, Bigelow, pp. 561-573; *Elementary Zoölogy*, Galloway, pp. 380-395; *Practical Zoölogy*, Davison, pp. 342-354; *Elementary Zoölogy*, Kellogg, pp. 403-409; *Economic Zoölogy*, Osborne, pp. 465-480; *Economic Zoölogy*, Kellogg and Doane, pp. 335-347; *Elementary Text*, Linville and Kelly, pp. 101-115; *Animal Life*, Jordan and Kellogg, pp. 114-148; *Animal Studies*, Jordan, Kellogg and Heath, pp. 281-289; *Elements of Zoölogy*, Davenport, Chap. 21; article on "Evolution" by Huxley in *Encyclopedia Britannica*.

SUMMARY

1. Evolution idea very old.
2. Lamarck's theory of the inheritance of acquired characteristics not accepted; not now considered correct.
3. Charles Darwin, 1859, "Origin of Species by Natural Selection."
4. The theory of natural selection, to account for origin of species.
 - (1) Over production.
 - (2) Struggle for existence.
 - (3) Variation.
 - (3) Survival of the fittest.
 - (5) Inheritance.
 - (6) Origin of better adapted forms.
5. Some conclusions from the theory.
 - (1) Accounts for adaptations.
 - (2) Indicates relationship of all forms.
 - (3) The "tree" line of descent.

- (4) Present system of classification.
- (5) Accounts for fossil series.
 - Accounts for embryo repetition.
 - Accounts for geographic distribution.
- 6. Evolution does not teach
 - (1) The "ladder" line of descent.
 - (2) The man-monkey descent.
 - (3) That evolution leaves God out.

NOTE. — Darwin did not originate the evolutionary idea, at all, as many seem to think; that was a very old belief. What he did was to prove that natural selection was the *means* by which evolution was brought about. There are doubtless other forces assisting natural selection in carrying on this development, some of which are fairly well understood.

CHAPTER XXXVI

THE DEVELOPMENT OF CIVILIZED MAN

Vocabulary

Anthropology, the study of the development of man.

Diffidence, hesitation.

Obviously, plainly.

Relatively, comparatively.

Acquisition, something just obtained.

Degenerate, less developed than formerly.

We have been studying the development of living things and man's relation to them, which brings us to another even more fascinating branch of biology, the development of man himself, a science called Anthropology.

We naturally think of man's development in terms of recorded history, but we must remember that writing is a very recent art and man's actual written records go back relatively but a little into the far past from which we are still emerging. Greek writings take us back about one thousand years B.C., Chinese, Egyptian, and Arab records may possibly date as early as 3000 B.C., but civilization was far older, and man, as a more or less human animal, much older still. Monuments and inscriptions may push back the boundary by vague information covering perhaps ten thousand years, though there is much dispute, and the data are uncertain.

Still further back amid the mists of human history we draw conclusions from bones and stone implements, showing that man existed as early as the glacial period, and was contemporary with the cave bear, mammoth, and aurochs, all now extinct. One ventures with diffidence to set a time in years for the date of these remote ancestors of ours, but apparently human animals, erect, large-brained, using weapons and tools, possessing the power of speech,

and perhaps the use of fire, existed one hundred thousand years ago.

Primitive man apparently had a much smaller brain capacity than his modern descendants, a lower forehead, sloping brow, heavy jaws, and receding chin. Still he was obviously human and, even then, intellectually far superior to the other Primates.

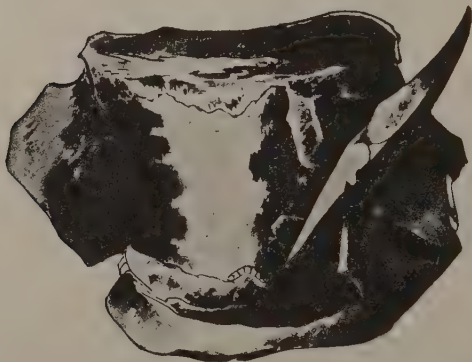


FIG. 107. Vertebra of young reindeer with flint arrowhead imbedded in the bone. From the Cave of Perigord, France. After Lartel and Christy. See Kellogg.

His earliest home must have been in relatively warm climates where nature provided food and shelter for her chil-

dren too ignorant to obtain them for themselves. His food was fruit and nuts and such animals as he could capture, unarmed,

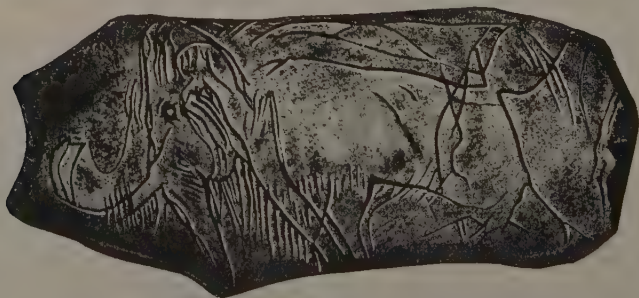


FIG. 108. Drawing of mammoth on piece of mammoth tusk. From the Cave of the Madeleine in Southwest France. The drawing was made by prehistoric man of the early Post-Glacial times. One-third size of original. From Kellogg.

and eat uncooked. This restricted his flesh foods mainly to clams and oysters, to which the enormous shell deposits still bear testi-

mony in many places in central Europe. Evidently man soon devised weapons, clubs, and spears perhaps, and later bows and arrows. Then he became a wandering hunter having no fixed home and changing his abode whenever game became scarce in any one locality.

With a widespread scarcity of game came the necessity of taming and raising food animals. Thus we have the herdsman wandering with his flocks from place to place, as pasturage and food were exhausted. Domestication of animals probably began with taming



FIG. 109. Remains of the Neanderthal man, in the Provincial Museum of Bonn. From *Weltall u. Menschheit*, see Kellogg.

the wolf to aid him in the hunt, but the real progress was made when tame cattle, sheep, and goats, partly took the place of wilder game.

A wonderful advance was made when man hit upon the idea of cultivating food plants for his flocks and himself. This permitted a fixed habitation and for the first time, a real "home life" had a chance to develop, with all that it means in comfort and social progress. Doubtless the house was but a cave or tree shelter, but when man settled to remain in one place, to cultivate and gather

his simple crops, community life and society had their earliest beginnings.

Man's development is usually classified by the implements he had learned to use.

1. *Primitive Man*. Without weapons, tools, or fire.
2. *Old Stone Age*. Stone weapons and tools, probably used fire. Contemporary with mammoth and cave bear.

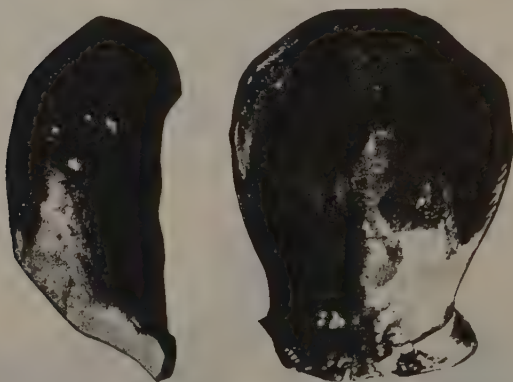


FIG. 110. Skull cap of *Pithecanthropus erectus*, the fossil man-like ape of Java. Shown from above and in profile; from Weltall u. Menschheit, see Kellogg.

3. *New Stone Age*. Used polished stone implements. Perhaps made crude pottery. Erected stone monuments, buried the dead. A period of many wars and migrations.
4. *Age of Metals*.
 - (a) Copper and gold first used because found pure in nature; could be shaped by hammering and did not have to be melted.
 - (b) Bronze, an alloy of melted copper and tin which made excellent implements and did not require great heat to melt.
 - (c) Iron, required skillful smelting and tempering, needing much higher temperature. Best metal for all uses. Brings us down to modern times.

TABLE I.

Showing Conditions in Europe during the Development of Man
Adapted from Osborn's "Men of the Old Stone Age"

Time	Climate COLD WARM	Animals	Implements	Human races
Postglacial 25,000 years		Deer, bison, horse, chamois, ibex	Iron 1000 B.C. Bronze 1000 yrs. Pottery Polished stone 5000 yrs.	Homo sapiens Brain capacity 2000 cc. Cro-magnon Race Brain capacity 1800 cc.
Glacial Period 25,000 years		Reindeer, arctic fox, muskox		
3. Interglacial Period 100,000 years		Bison, horse, hippopotamus, elephant, lion, rhinoceros, sabre-tooth tiger.	Carving, painting Clipped flints 25,000 yrs. Rough flints 25,000 yrs.	Neanderthal Race Brain capacity 1600 cc. Piltdown Race Brain capacity 1400 cc.
Glacial Period 25,000 years		Reindeer, wooly mammoth		
Interglacial Period 100,000 years		Hippopotamus, rhinoceros, elephant, stag, bison, horse		Heidelberg Race
Glacial Period 25,000 years		Reindeer, wooly mammoth.		
Interglacial Period 5,000 years		Hippopotamus, elephant, rhinoceros.	(Eoliths?)	
Glacial Period 5,000 years		Muskox in England.		(Trinil race lived in Java) Brain capacity 900 cc.

FIG. 111. From Pearse.

The period of written history extends back at most, only into the bronze age so we can see how comparatively recent has been our modern development, and how slow was man's progress in his earlier stages.

With our modern civilization has come a complete change in the manner of life. While we would not relish going back to the life of the cave dweller, still we pay a penalty for our safer and easier methods of living. Primitive man, if he survived at all, was necessarily a hardy, outdoor animal, eating hard foods, having a sturdy and little protected body, and literally "earning his bread by the sweat of his brow." Now we have so learned to control our environment that we live quiet, safe, indoor lives, protect our tender bodies with houses and clothes, and provide ourselves with soft



FIG. 112. At right, a carved flint from Denmark, of the Old Stone Age; at left, a polished stone axe head from Ireland, of the New Stone Age. From Kellogg.

and delicate cooked foods. On the other hand we have developed our brain and nervous system so that it has to take over the work previously done by muscle and brawn. Hence we are overworking our latest acquisition, our intelligence, at the expense of our bodies.

Is it any wonder then that we now have fat and flabby muscles, weak lungs, delicate skin, and degenerate teeth, combined with overworked nerves? If we are to develop to its highest efficiency the wonderful mind which the Creator has given us, we have to

make special effort to keep our bodies strong, even though physical strength is no longer the one essential in the struggle for existence.

To this end modern civilization is attempting, by healthful living conditions, by education in biology and hygiene, and by systematic exercise, to maintain as healthy a body as that of our ancestor with the stone hatchet, combined with all the marvelous abilities and achievements of the civilized mind.

We do not have to depend wholly upon the evidence of human remains to get an idea of how our ancient ancestors lived. Some Australian and African races are still almost in the stage of primitive man. Some central African tribes have no houses but sleep in what are practically nests; they hunt with stone clubs, do not know the use of even the bow and arrow, cultivate no crops, and eat human flesh. Certain natives of Patagonia are still living in the Stone Age so far as their culture is concerned. New Caledonia furnishes examples of man but little further advanced, and some tribes of Ceylon and Australia are living in even more primitive stages of development. Still, low as this culture may be, it is yet wholly unapproached or resembled by the life of the lower animals.

Anthropologists classify the human species in different ways, but are generally agreed upon four, or perhaps five races, distinguished about as in the following table:

Race	Habitat	Characteristics	Culture
Malay	Pacific islands Australia New Guinea	Dark skin Straight or wavy hair Fairly developed bodies	Lowest stage, some lack fire Language very primitive Rapidly disappearing
Ethiopian	Central Africa	Black skin and eyes Wooly hair Full jaws and long skull	Negrillo dwarfs almost as low as Australians No homes, or crops Use bows, cannibals Others much higher, negroes
American	Whole western hemisphere	Brown skin Straight black hair	Very high civilization in ancient Peru and Mexico Fine stone builders. Worked in gold and copper Had crops and domestic animals Patagonians now lowest type
Mongolian	China, Japan, India	Yellow skin Coarse black hair Flat nose Oblique eyes Very numerous	Ancient civilization very high. Developed all world religions except Christianity Invented written language
Caucasian	Western Asia and Europe Now widespread Not from the Caucasus	White skin Fine hair Regular features	Highest modern civilization as found in all white races

COLLATERAL READING

Primer of Evolution, Clodd, Chap. XI; *Story of Primitive Man*, Clodd, entire; *Story of Creation*, Clodd, entire; *Whence and Whither of Man*, Tyler, pp. 211-308; *Winners in Life's Race*, Buckley, pp. 333-353; *Animal Life*, Thompson, pp. 320-350; *Man Before Metals*, Joly, entire; *Anthropology*, Tyler, entire; *The Next Generation*, Jewett, pp. 153-161.

SUMMARY

1. Records of ancient man from
 - Written history.
 - Monuments and inscriptions.
 - Stone implements and remains.
 - Human bones.
2. Characteristics of primitive man.
 - Brain larger than other animals.
 - Brain smaller than present man.
 - Low forehead and sloping brow.
 - Heavy jaw and receding chin.
3. Stages of development in occupation.
 - Primitive man without weapons or fire.
 - Hunter, using spear, bow and arrow, able to control fire.
 - Herdsman, wandering for food supplies, domestication of animals.
 - Cultivator of the soil, permanent home, crops stored for future.
4. Stages of development in implements used.
 - Primitive man without implements.
 - Old Stone Age.
 - New Stone Age.
 - Age of Metals
 - Copper.
 - Bronze.
 - Iron.
5. Results of present higher mental development.
 - Body less strong and hardy.
 - Brain greatly developed and may be overworked.
6. Races of modern man.
 - (See tabulation in text.)

CHAPTER XXXVII

FOOD

Vocabulary

Assimilated, made like and built into tissue.

Calorie, the amount of heat used to raise a pound of water 4 deg. F.

Ratio, proportion.

Lipoid, a tissue building substance, somewhat like fats.

Vitamines, active substances in some foods, necessary to health.

All living things are alive because energy is liberated within them. This energy depends upon oxidation and oxidation involves the union of oxygen with the living tissue. This process destroys the substances oxidized, leaving behind waste products, carbon dioxide, water, and nitrogenous compounds, and necessitating the replacement of the oxidized tissue. Replacement of tissue means the taking in of *food*, which is a vital necessity to all living organisms.

If food is assimilated faster than it is used, growth, or storage of excess, results. In plants little energy is liberated and growth may be continuous; in animals a point is reached where oxidation balances assimilation and growth practically ceases.

Definition. Food may be defined as any substance which, when taken into a living organism, produces energy or builds tissue. The energy is necessary for any life, the tissue building may be to repair used organs or for increase in growth.

The chemical composition of all living things is much the same. They are composed of a small number of elements and all depend upon the vitality of protoplasm for their life. (See ch. 3, 4, 5.)

Naturally the foods that produce these living tissues are also similar in composition, though numerous in kind. The general classes of food stuffs (nutrients) have been discussed in Chapter 4,

where their composition and properties are tabulated, and grouped as inorganic and organic matter. Here we shall take up their functions in relation to the life and growth of animals, especially as food for man.

Functions of Inorganic Foods. *Water* constitutes about sixty per cent of all animal tissue, usually more than that in plants. It is a necessity to plants in starch making and in both plants and animals as a transporter and solvent for other foods. Though not oxidized in the body it is a very essential part of all foods.

Mineral salts compose about five per cent of all animal tissue. They are essential in formation of bone, teeth, blood, digestive fluids, and are used to supply nitrogen, sulphur, phosphorus, and iron for making protoplasm. Table salt, sulphate and phosphate of lime, and various nitrates are important examples.

Functions of Organic Foods. *Proteids* are the only food stuffs containing nitrogen, and are therefore absolutely essential in production of living tissue. They include some of man's most valuable foods, such as lean meat, white of eggs, cheese, gluten in wheat, legumin in peas and beans, etc. Proteid matter constitutes about eighteen per cent of the weight of man's body. The chief function of proteid foods is to build tissue. They build anew and repair muscle and tendon, bone, cartilage, and skin and also compose the corpuscles of the blood. Proteids may also be oxidized directly and thus may be used to furnish energy. While this actually takes place to some extent, it would be an expensive source of fuel and it would also put too great a strain upon the digestive and excretory organs if all energy were sought from this class of foods.

The fats and carbohydrates are the chief energy producers. The former occur in fat meats, butter, fish, and eggs among animal foods, and in olive and cotton seed oils, nuts, corn, and cocoa from the vegetable world. The amount of fat needed varies with age, occupation, and other conditions but if more is taken than is required, it may be stored, almost unchanged, to be drawn upon if the energy supply becomes short. About fifteen per cent of the human body is fat tissue and much of our energy is derived from other amounts that are oxidized directly.

Carbohydrates (starches, sugars, and cellulose) comprise the bulk of man's nourishment. They are found in all vegetable foods, grains, potatoes, fruits, and nuts. Milk furnishes an important animal sugar. Though occupying so large a place in our menu, carbohydrates compose hardly one per cent of the body's weight. This is because they are easily oxidized, furnishing much heat and energy and if any excess is taken, it is changed into fat and stored as such.

Thus it is seen that while proteid, fat, or carbohydrates may all supply energy, neither of the latter can perform the proteid's function in growth and repair of tissues. However, the fats and carbohydrates serve to protect the valuable proteids by being first oxidized and saving the proteids for tissue building which they alone can perform. (See "Summary of Nutrients" at end of chapter.)

Measurement of Food Values. There is no way of measuring the tissue-building value of foods. But, since all may produce heat and energy, they may easily be measured and their value as food computed in terms of heat produced. The unit of measurement is the "calorie" which is the amount of heat required to raise the temperature of one pound of water four (4) degrees Fahrenheit. Very careful experiments have shown that a man in an average day's work requires food enough to produce 2800 calories of energy.

The amount of energy (number of calories) required varies with age and occupation as shown in this table.

TABLE I
DAILY CALORIE NEEDS (APPROXIMATELY)

1. For child under 2 years	900 calories
2. For child from 2-5 years	1200 calories
3. For child from 6-9 years	1500 calories
4. For child from 10-12 years	1800 calories
5. For child from 12-14 (woman, light work, also)	2100 calories
6. For boy (12-14), girl (15-16), man sedentary	2400 calories
7. For boy (15-16), (man light muscular work)	2700 calories
8. For man, moderately active muscular work	3000 calories
9. For farmer (busy season)	3200 to 4000 calories
10. For ditchers, excavators etc.	4000 to 5000 calories
11. For lumbermen, etc.	5000 and more calories

The energy required for various degrees of exercise are shown below and one can compute the number of calories used per day by multiplying the calories per hour by the hours of each kind of exercise per day. Do this and see how near it comes to the estimate for a person of your age in Table I.

TABLE II
AVERAGE NORMAL OUTPUT OF HEAT FROM THE BODY

Conditions of Muscular Activity	Average Calories per Hour
Man at rest, sleeping	65 calories
Man at rest, awake, sitting up	100 calories
Man at light muscular exercise	170 calories
Man at moderately active muscular exercise	290 calories
Man at severe muscular exercise	450 calories
Man at very severe muscular exercise	600 calories

Food Proportions. In order that the body may have tissue building foods and fuel foods in healthful proportions, we ought to eat from two to three ounces of proteid per day, and enough fats and carbohydrates to make up the number of calories which we may require as indicated above.

Since the fuel value of carbohydrates is only $\frac{1}{2}$ to $\frac{1}{3}$ that of fats, our diet should have two or three times as much carbohydrate, especially in warm weather, when the concentrated fuel of the fats is less needed. Still another way of reaching the same result is to take $\frac{1}{80}$ ounce of proteid for each pound of our weight, and enough of the fuel foods (fats and carbohydrates) to make up the required number of calories, for energy production. This makes a diet rather low in proteid especially for growing children, but our usual mistake is to use too much, rather than too little proteid, and one good authority sets the amounts even lower.

A safe proportion for growing boys and girls would be about 2 or $2\frac{1}{2}$ ounces of proteid per day, and enough fuel foods to supply the required energy, which will depend upon the age and activity as already stated.

The carbohydrates ought always to be more abundant than the fats, because of the much greater amount of energy produced by the latter. This is especially true in warm weather, when the proportion of four times as much carbohydrates will be about the proper diet.

If the above proportions are followed for all three food stuffs, the ratio for all will be about, —

Proteid, one; fat, one; carbohydrate, four.

Need of Mixed Diet. We require proteids, fats, and carbohydrates in about the proportions 1:1:4 but there is no one food that contains these nutrients in these proportions, so it is evident that a mixed diet is necessary. When foods are properly selected, so that the above proportion is obtained, we have what is known as a “balanced ration” and this should be the aim, both of those who prepare and those who eat foods.

If we use a diet largely of lean meat, we have too high a per cent of proteid. This excess is thrown off by the kidneys and intestines as waste. It overtaxes these organs seriously and is an expensive and unnecessary form of diet. In the same way an excess of fat much above the given proportion, such as would come from a diet rich in fat meats and butter, merely wastes the extra energy or stores it as unnecessary fat tissue in the body.

A strict vegetarian diet is almost sure to be too rich in carbohydrates and has the same result as do fats, fuel is wasted, too little tissue material is provided, and fat tissue may also accumulate from the starches being transformed and stored in this form.

Remember that, in general, most of the energy should come from carbohydrates and fats, and only enough proteid be taken, to provide for tissue building and repair. If our diet proves to be high in proteid, we are burning tissue foods for fuel, as well as putting extra strain on our system, to remove the nitrogenous waste left by proteid oxidation.

In general, man has learned to combine foods, to correspond, roughly, to these needs as will appear if we look up the composition of familiar combinations, like the following,—

“Meat and potatoes,” “Bread and butter,” “Bread and milk,”

"Bread and cheese," "Pork and beans," "Potato and gravy," "Cereal and cream," "Ham sandwich."

A study of the following table will show the number of ounces of proteid, and the fuel or energy values, of some of our common foods. The amounts of each food stuff taken are about the usual portion or "helping" which one would receive at table, so we can calculate how much proteid and energy our present diet provides, and see if it corresponds to the amounts mentioned as suitable for our age and occupation.

From this table, also, it is possible to determine whether one's diet has the proper proportion of fat and carbohydrate, in proportion to the proteid, if one is using the 1 : 1 : 4 ratio as a basis.

These tables are used through the courtesy of Professor Frank H. Rexford, from whose "One Portion Food Tables" they are taken. They furnish the easiest means of estimating whether one's diet is properly balanced.

Digestibility of Foods. Not only must the nutrients in our foods be present in the proper proportions, but they must be in a digestible form, or else they are wasted. Careful study shows that vegetable proteids and fats are not so easily digested as those from animal foods, though they seem to be cheaper.

This means that we must either use considerable animal food, or else increase the apparent amount of vegetable proteids and fats beyond the proportion suggested in the tables, because the body does not so readily digest them. This fact balances their cheaper cost to a great extent, and is also evidence that man is intended for a mixed diet, obtaining much fat and proteid from animal sources, and his carbohydrate foods from the plants.

Cost of Foods. Not only must our diet be selected with reference to proper amounts of the nutrients and ease of digestibility, but also with regard to the cost in money. This is affected by three things, the actual price of the food, the amount of water and waste, and the expense of preparation. It is more and more important that we shall be informed as to the composition and cost of foods, and for this purpose the Government has published many bulletins, which can be had free of cost, by application to the Department of

FOODS PRIMARILY OF PLANT ORIGIN

FOOD AS WE EAT IT	OF THIS THE BODY CAN USE			This Portion can Yield to the Body in Energy and Heat Units
	Muscle Builder	For Heat and Energy		
	Proteid	Fat	Carbo- hydrates (Starch and Sugar)	
	Ounces	Ounces	Ounces	Calories
<i>Beverages</i>				
Cocoa.....	.11	.33	.19	123
Coffee (cream and sugar only).....	.01	.17	.27	53
<i>Bread</i>				
Biscuit, soda.....	.19	.27	1.05	216.3
Bread, corn.....	.16	.09	.93	150.6
“ graham.....	.18	.04	1.04	151.3
“ wheat.....	.18	.03	1.07	153.1
“ plain rolls.....	.19	.08	1.2	182.08
“ and butter.....	.22	.48	1.18	275
Crackers, saltines.....	.11	.13	.69	125.3
“ soda.....	.1	.09	.73	120.3
Toast, dry.....	.06	.008	.3	44.4
<i>Cake</i>				
Chocolate, layer.....	.14	.2	1.6	256.8
Cookies, molasses.....	.13	.16	1.32	209
Doughnuts.....	.12	.37	.93	218.8
Frosted.....	.12	.18	1.3	211.9
Fruit.....	.12	.22	1.28	220
Sponge.....	.09	.16	.9	168.3
<i>Cereals</i>				
Corn flakes.....	.07	.003	.59	77.6
Oatmeal.....	.13	.02	.49	76.5
Puffed rice.....	.04		.4	50.9
Rice.....	.11	.001	.96	124.72
Shredded wheat (2).....	.21	.03	1.56	212.5
<i>Fruit</i>				
Apple, baked.....	.02	.02	.78	98.5
Bananas.....	.05	.02	.77	100.8
Olives, green.....	.01	.37	.15	116.3
Oranges.....	.04	.01	.58	75

FOODS PRIMARILY OF PLANT ORIGIN. — *Continued*

FOOD AS WE EAT IT	OF THIS THE BODY CAN USE			This Portion can Yield to the Body in Energy and Heat Units
	Muscle Builder	For Heat and Energy		
	Proteid	Fat	Carbo- hydrates (Starch and Sugar)	
	Ounces	Ounces	Ounces	Calories
<i>Miscellaneous</i>				
Brown gravy	.03	.26	.07	81.2
Hash, beef	.26	.27	.32	114.3
Macaroni	.36	.02	2.00	286.2
Salad dressing (French)		.74	.02	100.4
<i>Nuts</i>				
Almonds	.05	.14	.04	47.8
English walnuts	.08	.32	.08	103.4
Peanuts	.13	.19	.12	80.1
<i>Pie</i>				
Apple	.29	.31	1.44	282.8
Lemon	.14	.4	1.4	297.2
Mince	.65	.42	1.51	362
Pumpkin	.15	.15	1.	177
<i>Pudding</i>				
Blanc mange (chocolate)	.1	.3	.49	148.8
Custard	.16	.16	.35	102.4
Rice	.12	.28	.55	149.5
Tapioca	.11	.1	.92	146.3
<i>Salad</i>				
Egg mayonnaise	.26	.25	.02	100.1
Fruit	.04	.02	.52	70.4
Potato	.09	.22	.29	102.1
Tomato (with mayonnaise)	.06	.16	.15	67.6
<i>Soup</i>				
Bean	.38	.07	1	182.8
Cream of celery	.11	.34	.17	124.8
Consomme	.1		.02	16
Clam chowder	.09	.04	.33	60
Tomato	.13	.12	.33	91.2
Vegetable (canned)	.13		.02	192.8

FOODS PRIMARILY OF PLANT ORIGIN — *Continued*

FOOD AS WE EAT IT	OF THIS THE BODY CAN USE			This Portion can Yield to the Body in Energy and Heat Units
	Muscle Builder	For Heat and Energy		
	Proteid	Fat	Carbo- hydrates (Starch and Sugar)	
	Ounces	Oun es	Ounces	Calories
<i>Sugars</i>				
Candy, chocolate.....	.01	.01	.73	90
Chocolate, almonds.....	.06	.15	.95	160
Maple syrup.....			.89	103.9
Sugar (granulated or loaf).....			.25	27
<i>Vegetables</i>				
Beans, baked.....	.31	.18	1.08	182
“ kidney.....	.22	.65	.6	97.5
“ string.....	.69	.61	.21	48.72
Beets.....	.05	.002	.15	26.1
Cabbage, boiled.....	.03	.09	.16	35.2
Celery.....	.01	.003	.04	5.5
Corn, canned.....	.08	.03	.52	74.25
Carrots.....	.04	.02	.35	49.2
Lettuce.....	.01		.03	7
Onions, creamed.....	.04	.15	.15	65.7
Peas, canned.....	.09	.09	.54	66.6
Potatoes, sweet.....	.09	.06	1.26	173.4
“ white, mashed.....	.09	.26	.68	100.4
“ “ baked.....	.1	.01	.26	98.1
Succotash.....	.11	.03	.56	78
Tomatoes, sliced.....	.04	.04	.18	26.8
“ stewed.....	.08		.08	16.4

Agriculture at Washington. Lists of all publications will be sent on application.

While we cannot devote enough space to the topic to compare the different kinds of food, their cost and composition, and methods of preparation, even a slight study of your own diet, in the light of this chapter, will show two facts: first, Americans eat more food

FOODS PRIMARILY OF ANIMAL ORIGIN

FOOD AS WE EAT IT

OF THIS THE BODY CAN
USEMuscle
BuilderFor Heat and
Energy

Proteid

Fat

Carbo-
hydrates
(Starch
and
Sugar)This Portion can Yield
to the Body in Energy
and Heat Units

	Ounces	Ounces	Ounces	Calories
<i>Beef</i>				
Corned.....	.21	.52		174.2
Dried.....	.26	.07		49.4
Round.....	.43	.29		125.2
Sirloin.....	.37	.36		137.1
<i>Dairy Products</i>				
Butter.....	.05	.43		112.5
Cheese, full cream.....	.26	.34	.02	122.4
Ice cream.....	.05	.1	.91	134.7
Milk, whole.....	.19	.24	.3	123.6
Oleomargarine.....		.4		110.2
<i>Eggs</i>				
Boiled (2).....	.49	.45		179.1
Omelet.....	.48	.88	.03	296
Scrambled.....	.24	.17	.03	78.5
<i>Fish</i>				
Cod.....	.32	.02		101.6
Halibut, steak.....	.56	.16		105.9
Salmon, canned.....	.44	.24		114.1
<i>Fowl</i>				
Chicken (fricasseed).....	.62	.4	.08	187
Turkey.....	.26	.26		104
<i>Lamb</i>				
Chops (broiled).....	.43	.59		210
Leg.....	.67	.44		194.3
<i>Mutton</i>				
Leg.....	.62	.51		108

FOODS PRIMARILY OF ANIMAL ORIGIN—*Continued*

FOOD AS WE EAT IT	OF THIS THE BODY CAN USE			This Portion can Yield to the Body in Energy and Heat Units
	Muscle Builder	For Heat and Energy		
	Proteid	Fat	Carbo- hydrates (Starch and Sugar)	
	Ounces	Ounces	Ounces	Calories
<i>Pork</i>				
Bacon	.1	.66		188.6
Chops	.47	.95		309
Ham, lean	.49	.55		203.2
<i>Sandwiches</i>				
Cheese	.41	.49	1.2	314.2
Egg	.4	.37	1.19	279.7
Ham	.33	.48	1.19	302.7
<i>Sausages</i>				
Country	.56	.8		278.1
<i>Shell fish</i>				
Clams	.24	.02		32.2
Lobster	.32	.04		47.6
Oysters	.21	.04		36.4
<i>Veal</i>				
Cutlets	.7	.26		152
Leg	.65	.1		104
Liver	.56	.17		107.1

than is required and second, they have an idea that the most expensive foods are the most nutritious.

These are serious mistakes, overtaxing both the digestive system and the pocket book, and no subject of our study is more important than the one giving us a clear idea of food values and selection.

Right and Wrong Diets. We are all too apt to let our artificial "tastes" and the demands of fashionable customs over-rule our

natural instincts and better judgment in the selection of foods. Costly, highly-seasoned, stimulating, and unnatural substances are frequent invaders of our digestive apparatus, to the detriment both of our bodies and our bank accounts. For the majority of people in normal health, meats, fish, eggs, milk, butter, cheese, sugar, flour, meal, potatoes, and other vegetables make a fitting and sufficiently varied diet — the main point being to use them in proportions suited to the actual needs of the body and not according to acquired whims of the “appetite.”

Another fact that is often misunderstood, even after a study of nutrients, is the very essential nature of mineral salts, especially



From the American Museum of Natural History.

FIG. 113. A U.S. soldier in the field is allowed a daily ration supplying 4199 calories of energy. A typical daily field ration supplying this amount of energy is shown above.

iron, calcium, and potash compounds, which we obtain from green vegetables, otherwise not rich in food value. As shown by the “Summary of Nutrients” on p. 357, these mineral compounds are a necessary, though small part of every properly balanced diet. Furthermore, the fact that many foods, especially of vegetable origin, contain considerable indigestible matter such as cellulose, or connective tissue, is also of value as supplying a certain *bulk* of matter required to keep the digestive apparatus properly filled and active.

A diet could be devised made up of highly concentrated and pre-digested foods, which, though giving all necessary nutrients, would be very harmful, because of relieving the digestive organs of the

work for which they have become adapted, and without which they will not remain in health.

Cooking. Man is the only animal which has learned to build a fire, hence is the only animal to use cooked food. This is not an unmixed blessing, for our digestive apparatus and especially our teeth are inherited from our animal ancestors, and, when provided with cooked food, are relieved of work for which they were adapted. This leads to disuse and so to degeneration. One seldom hears of the lower animals suffering from decayed teeth or indigestion, both of which are almost universal in man, due partly to too abundant, too delicately prepared, and unnatural foods.

Cooking of food performs three functions: First, it changes the mechanical and chemical condition so as to make it more easily digestible; second, it makes food more appetizing in appearance or flavor, which quickens the flow of digestive fluids and actually aids digestion; third, the high temperature kills any dangerous bacteria, organisms, or parasites that the food may contain. This is very important.

Cooking meat develops its pleasing taste and odor, softens connective tissue, and makes it "tender," though too high temperature may harden the proteids of the lean portions. Beef extracts and thin soups are very agreeable to the taste, but contain very little nourishment since the meat proteids and fats are not soluble in water. These broths are useful as appetizers or mild stimulants but are of slight value as food.

In *cooking eggs*, especially by frying, the proteid (albumen) is hardened and made less digestible than in the raw state. *Milk*, also, if heated to boiling, is made less valuable as food; though when pasteurized the heat is regulated so as to kill most bacteria, but not to reach a point high enough to impair its food value. When the *vegetable foods* are cooked the changes are chiefly the softening of the cellulose and the breaking of the insoluble walls around the starch grains, thus exposing them to digestive fluids and partly dissolving the starch in the hot water or steam.

In *baking* all flour foods, the aim is to make the material "light," and porous so as to be more easily broken up and digested in the

alimentary canal. This lightness may be secured by the mere expansion of steam in the dough, but it is usually caused by use of yeast or baking powder, which produce carbon dioxide within the batter. The gluten (proteid), always present in flour, is sticky enough to retain the gas, which expands with the heat of cooking, filling the loaf with countless bubbles and making it porous. Finally the heat stiffens the gluten and starch and drives out much of the enclosed gas and we have the "light," porous, and digestible bread or pastry, instead of an indigestible paste of uncooked flour and water.

"Special Foods." There are no foods for special organs. Fish is not a "brain food," nor celery a "nerve food," nor meat a "muscle food." The savage eats the heart of his fallen foe to absorb his courage, but we ought to be beyond that stage. If we use a properly balanced diet our cells will select what they need in proportion as we use them. The only way to increase the brain power is to use the brain, — not by eating foods rich in phosphorus because the brain tissue contains this element.

If eating strong muscle made us strong, we ought to have a diet of the toughest meat possible. However the only way to persuade nature to give us more strength, is by using what we have and furnishing her a proper food supply to select from.

To be sure, if phosphorous compounds are lacking, the nerves will suffer; if proteid be absent, our muscle tissue might feel the lack, but in a balanced diet this is never the case. An excess of any element, above what is normally used in the body, does not develop any special part, but is merely wasted. Extra proteid is not needed for extra work; it is the fuel food that supplies the energy, the proteid requirement being almost constant for all grown persons and only slightly varying for younger people.

Lipoid. A shortage of fat in the diet, not only reduces the energy produced, but has long been associated with a lowering of nervous activity. This is now explained by the discovery of a substance called lipoid, in the cell walls of the body, especially in the outer layer of the nerve fibers and brain cells.

Lipoid resembles fat in many ways, but contains nitrogen and

phosphorus which ordinary fats do not. It is affected by alcohol, anaesthetics, and poisons and thus may be the means by which these act upon the system. At all events it seems to be derived from fat foods and is very essential to the nervous system.

Vitamines. It has been found that a diet restricted to a few foods, especially if they all be cooked, does not always result in proper nourishment, even though the balance may seem to be correct. This has led to the belief that there are substances called vitamins in certain foods, which are necessary to health and are destroyed by cooking. In order to supply these, the diet should include a moderate amount of uncooked foods, such as fruits, lettuce, celery, tomatoes, milk, and butter.

Fruits and vegetables are important for another reason. They produce alkaline substances when digested and these neutralize harmful acids formed by the digestion of proteids. They are also our chief source of iron and some other necessary mineral salts, and cannot be safely omitted from the dietary, even though their calorie value is not always very high.

If energy alone was all that is required of food we could get our 2500 calories from about twenty ounces of sugar or white of egg, or half that amount of clear butter. Both our instinct and experience teach us that this would not support a healthful life.

Dietary Diseases. Certain natives of Japan and the Philippines live largely on rice. This supplies plenty of energy but lacks other essential nutrients and they suffer from a disease called beri-beri, which is quickly cured by a change of diet. Pellagra is a sickness which occurs in our southern states, and seems to be caused by a diet poor in proteid. Scurvy is another dietary disease, caused by lack of fresh fruits and vegetables. It used to be common among sailors whose long voyages forced them to live on salt meats without any fresh foods, and was promptly relieved by use of fruit and fruit juices when they came ashore. Long ago the sailing vessels used to carry casks of lime juice to prevent this, and now it has become a custom to refer to any sailor on a slow sailing vessel as a "lime juicer."

Experience teaches that

1. Food must be sufficient in amount.
2. Diet must contain proper proportion of the nutrients.
3. Diet must contain vitamins.
4. Diet must include a considerable variety of foods.

SUMMARY OF NUTRIENTS

Nutrients	Composition	Function	Foods containing
Proteids	C, H, O, N, S, P, K, Ca, Cl, Fe	Build tissue Protoplasm Some energy	Lean meats, eggs, beans, peas, milk
Carbohydrates	(C, H ₂ , O)	Energy Stored as fat Some tissue	Sugar, cereals, bread, corn meal
Fats and oils	(C, H) O	Energy Stored as fat	Butter, lard, milk, cheese, olive oil, nuts
Water	H ₂ O	60% tissue Blood, fluids Transporter	Taken as water in all vegetables fruits, all foods

Mineral Salts			
Phosphates	H ₃ PO ₄	Bone Protoplasm Aid digestion	Grains (whole) meats, fish, milk
Salt	NaCl	Essential in blood Appetizer	Taken as salt in almost all food
Iron compounds	FeCO ₃	Haemoglobin Oxygen carrier	Spinach, lettuce, green foods, prunes, meats
Potassium compounds	K ₂ SO ₄	Essential in blood	Vegetables
Calcium and magnesium compounds	Ca, Mg	Regulate nerve and heart action	Grains (whole) Vegetables

NOTE. — Look up tests for as many of the above as you can.

NOTE. — There are many kinds of proteids as,

(1) Myosin in meats; (2) legumin in peas and beans; (3) casein in

milk and cheese; (4) gluten in grains; (5) albumin in eggs; but all contain *nitrogen*.

There are many kinds of carbohydrates as,

(1) Several kinds of starches (corn, potato, sago, arrow root).

(2) Many kinds of sugars (cane, saccharose:—grape, glucose:—milk, lactose:—fruit, fructose).

(3) Cellulose.

(4) Gums and resins (some of them).

THE FUNDAMENTAL PRINCIPLES OF CORRECT EATING

The human body is very much like an engine. It needs fuel to keep it running. As it has to be built so must it be repaired from time to time, also it must be regulated, hence, we need A — Fuel food; B — Building or repair food; C — Regulating food.

Fuel Foods. As in the case of an engine, the main requirement is for fuel. Unlike an engine, however, if the human body does not secure sufficient fuel it will literally burn to death, the tissues being drawn upon to supply the fuel. On the other hand, the human engine may easily become overstoked by an excess of fuel. The following list shows the main fuel foods, the great foundation foods of the diet, that supply energy for muscular work. Mental work requires so little extra fuel that it is not necessary to consider it specially. There are three groups of fuel foods. Here they are in the order of their cost per calorie, those giving most energy for the money heading the list.

1. Starchy Foods

Cornmeal	Rice	Split peas, yellow
Hominy	Macaroni	Dried navy beans
Broken Rice	Spaghetti	Bread
Oatmeal	Cornstarch	Potatoes
Flour	Dried lima beans	Bananas

2. Sugars

Sugar	Candy
Corn syrup	Molasses
Dates	Most Fruits

3. Fats

Drippings	Peanut butter
Lard	Milk
Salt pork	Bacon
Oleomargarine	Butter
Nutmargarine	Cream

About 85 per cent of the fuel for the body should come from these groups, using starchy foods in the largest amounts, fats next, and sugar least.

Building and Repair Foods. These are divided into proteids and mineral salts.

1. **Proteid, or "Body Bricks."** These food elements are found in greatest abundance in lean meat of all sorts (including fish, shell food, and fowl), milk, cheese, eggs, peas and beans, lentils, and nuts. There is also a fair amount of proteid in cereals and bread (about 10 per cent), which are both building and fuel foods. Most foods contain some proteid. Those above-mentioned are richest in proteid and hence are termed "Building" or "Repair Foods."

The following is a list of the building and repair foods in the order of their cost, those giving most building and repair material for the money heading the list.

Beans (dried white)	Bread, whole wheat	Macaroni	Eggs (second grade)
Dried peas	Bread, graham	Mutton, leg	Halibut
Oatmeal	Salt cod	Beef, lean rump	Porterhouse steak
Cornmeal	Milk, skimmed	Milk	Eggs (first grade)
Beans, dried lima	Cheese (American)	Beef, lean round	Almonds, shelled
Bread	Peanuts	Lamb, leg	

2. **Mineral Salts.** These are found in milk, green vegetables, fruits, and cereals made from the whole grains, and egg yolks.

Regulating Foods. 1. **Mineral Salts.** These minerals which have been mentioned as repair foods, are also regulating foods and help to keep the machinery running properly.

2. **Water.** Water is an important regulating food. Many people drink too little. Six glasses of water a day is the average requirement — one between meals and one at meals.

3. **Ballast or Bulk.** This is furnished by cereals and vegetable fiber, which is found in whole wheat or Graham flour, in bran, leaves and skins of plants, and skins and pulp of fruits. Examples are: *Vegetables* — Lettuce, Parsnips, Carrots, Turnips, Celery, Oyster Plant, Cabbage, Brussels Sprouts, Tomatoes, Salsify, Spanish Onions, Spinach. *Fruit* — Apples (Baked or Raw),

Pears, Currants, Raspberries, Cranberries, Prunes, Dates, Figs, Oranges.

4. **Hard Foods.** Vigorous use of teeth and jaws is insured by hard foods, such as crusts, hard crackers, toast, Zwieback, fibrous vegetables and fruits, celery and nuts, which are necessary to keep teeth and gums in a healthy condition.

5. **Accessories or Vitamines.** These are minute substances (vitamines and lipoids) present in a very small quantity in a number of foods and apparently necessary to keep the body in health. That is, the absence of these elements seems to lead to poisoning of the body, which results in such disturbances as scurvy, beri-beri, and other so-called "deficiency" diseases. Milk, eggs, whole wheat, corn, oatmeal, potatoes and oranges, skins or hulls of cereals, fresh meat, fresh peas and beans are thought to contain them. It seems necessary to include the leaves of plants (green vegetables) when the seeds (cereals, grain, flour, etc.) are used as food if the diet is to be complete and well balanced. Fruit and vegetable acids are regulating. They keep the blood alkaline and prevent constipation.

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SUMMARY

Necessity of food.

Living things use energy.

Energy is released from food by oxidation.

Oxidation destroys tissue.

This tissue has to be replaced by food.

Excess of food used for growth or storage. (Compare plant and animal.)

Definition of food.**Functions of food-stuffs.**

Inorganic. Water (60%). Transportation, solvent (photosynthesis).

Mineral salts (5%).

Phosphates, chlorides, nitrates, carbonates.

(Compounds of N, S, P, iron, lime, etc.)

Used in bone, teeth, blood, fluids, digestion, etc.

Organic. Proteids (18%).

Composed of C, H, O, N, S, P, etc.

Essential to living tissue, protoplasm.

Found in lean meat, eggs, cheese, wheat, beans, peas.

Fats (15%).

Composed of C, H, O.

Easily oxidized, produce energy, excess stored.

Found in fat meat, butter, eggs, fish, lard, cotton and olive oil, corn, cocoa, etc.

Carbohydrates (little in tissues).

Composed of C, H₂, O.

Produce energy or stored as fat.

Found as sugar in cane, fruits, beets, milk.

Found as starch in vegetables, grains, nuts, etc.

Found as cellulose in most vegetable foods.

Measurement of food values.

Energy value measured in "calories."

About 2800 calories needed by average individual.

Needs vary with age and occupation.

Food proportions.

Proteids from 2 to 3 ounces per day.

Fuel foods to make up remaining number of calories,

obtained from $\left\{ \begin{array}{l} \text{fats, one part.} \\ \text{carbohydrates, two to four parts.} \end{array} \right.$

Less fats in warm weather.

Ratio about, proteid : fat : carbohydrates

(1) : (1) : (4)

Balanced Ration.

No one food has nutrients in correct ratio.

Hence a mixed diet is necessary.

Animal food would be too high in fat and proteid.

Vegetable food would be too high in carbohydrates.

Excess of proteid, a dangerous and expensive source of energy.

Digestibility of Foods.

Vegetable fats and proteids less digestible than animal.

Value of both vegetable and animal foods.

Cost of Food.

Depends on price, waste, cost of preparation

Expense due to poor selection.

bad preparation or waste.

demands of artificial appetite.

Proper Diet.

Value of simple, standard foods.

Objections to highly seasoned or "fancy" dishes.

Importance of green vegetables for mineral salts.

Concentrated foods not good, bulk needed.

Cooking.

Functions, makes food more easily digested.

makes food more appetizing.

sterilizes food.

Faulty cooking may make food less digestible

Boiling *vs.* pasteurizing milk.

Effect of cooking on teeth.

No Foods for Special Organs.**Lipoid.****Vitamines.****Dietary Diseases.**

CHAPTER XXXVIII

NUTRITION

Vocabulary

Nutrition, all processes concerned with building up tissue.

Alimentary, pertaining to food or nutrition.

Fallacy, a mistaken idea.

Distended, swelled up or expanded.

Lacteals, lymph capillaries of the intestine which absorb fat.

Someone has said, "We live, not on what we eat, but on what we digest." Food, even after cooking, is not usually in condition to be made into tissue or to furnish energy.

Digestion produces two important changes in foods. First, it makes them soluble to allow transfer by osmosis; second, it changes them chemically to permit them to be assimilated. These changes are brought about in two ways, first, *mechanically* by the teeth, the motion of the stomach, and intestinal walls, second, *chemically* by active substances in the digestive fluids, called enzymes or ferments. The latter are the more important means of digestion; there are several kinds, each acting on a particular foodstuff and each secreted by different glands in various parts of the digestive tract. They will be referred to later when these different regions are studied.

Digestive Organs. The digestive tract or alimentary canal is practically a continuous tube with many glands opening into it to furnish digestive fluids, also with a rich blood supply to provide for its activities and to remove digested foods. This food tube consists of three general regions whose structure and functions will be studied in order,

1. The mouth
2. The gullet and stomach
3. The intestines.

In the simpler animals the digestive canal may be lacking (protozoa), or almost straight and uniform in size (worms), but in

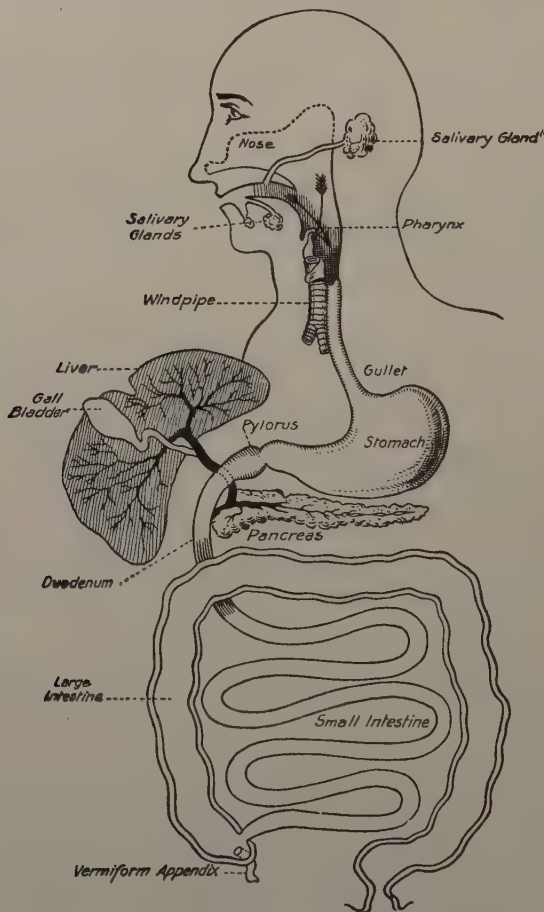


FIG. 114. Diagram of the alimentary canal. Modified from Landon's, see Kellogg.

the higher animals and man it is much coiled to provide greater surface for secretion and absorption, and also varies much in

diameter, to permit the carrying out of special functions in various parts.

The Mouth. So far as digestion is concerned, the mouth performs two functions: in it the food is crushed or cut into smaller portions and at the same time it is mixed with saliva, one of the digestive fluids, whose function will be dealt with later. The mouth cavity is bounded above by the palate, below by the tongue, and at front and sides by the teeth, lips, and cheeks. There are six openings into this cavity, from within, namely

1. Two nasal openings, behind the palate and connecting with the nostrils, above.
2. Two eustachian tubes, also far back, high up at the sides and connecting with the ears.
3. The trachea and gullet below, the former in front and connecting with the lungs, and the latter behind it and communicating with the stomach.

Other organs are immediately connected with the mouth cavity, most of which can be seen by studying your own mouth with a mirror or by looking into a friend's mouth with a small electric light. The "roof of the mouth" or hard palate can be easily recognized. Back of it is a downward projecting sheet of muscle, the soft palate; at either side rounded projections may be seen, which are tonsils.

Behind the soft palate and near the opening into the nasal cavity is the location of adenoid growths which may obstruct the breathing and have to be removed if they reach abnormal size. The tonsils also sometimes become enlarged and act as nests for bacterial growth, necessitating their removal. Their function is not thoroughly understood, and when diseased their removal is beneficial.

The openings of the eustachian tubes are protected by their high location and by folds of membrane beside them. The trachea is protected by the base of the tongue and the epiglottis, which is a door-like organ that covers the trachea during swallowing.

The Tongue. The tongue is easily studied, but few of us really know its shape, size or structure. The best way to find out is to

look at it. It is a large muscular organ, nearly filling the front part of the mouth cavity when the jaws are closed. It has great freedom of motion and performs the following functions:

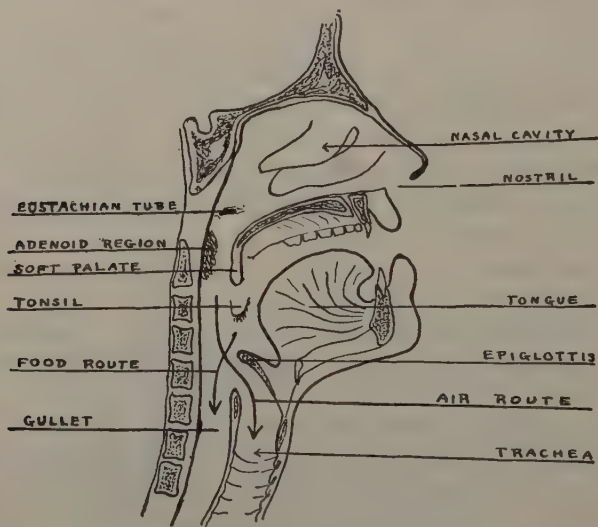


FIG. 115. Mouth and Throat.

The object of this plate is to show the relative position of the organs of the nose and throat, and especially to indicate the course taken by food in swallowing, and air in breathing.

Note that these routes cross each other, making necessary the adaptation mentioned in the text, to prevent food from entering the trachea when being swallowed.

Attention is called to the size and thickness of the tongue, which we usually think of as long and thin. Its base pushes back and the epiglottis closes down when the food is passing.

Note also the large size of the nasal cavity and the projecting lobes which help warm and moisten the air, catch dust, and provide surface for the nerves of smell.

1. It is the organ of taste — a sense which aids in selecting foods and in promoting their digestion.
2. It aids in chewing, by automatically keeping the food between the teeth.
3. It is concerned in the process of swallowing, since it rolls

the food into proper shape, pushes it back toward the gullet, and partly closes the trachea.

4. It helps to keep clean the inner surface of the teeth.
5. In man it is one of the organs concerned in speech.

The Teeth Structure. The teeth are even more familiar and important organs. Each consists of three parts, (1) the crown or exposed portion, (2) the neck, a slight narrowing at the edge of the gum, and (3) the root or roots which are attached to the jaw.

A section cut lengthwise through a tooth shows that the crown is covered by a very hard substance called enamel, which protects the exposed parts. The bulk of the tooth consists of dentine, a softer and more porous substance, while the center is occupied by the pulp which contains the nerves and blood vessels of the tooth. The root is covered by a bone-like coating, the cement, and through the very tip is the opening by which the nerves and blood vessels find entrance.

Number and Kinds of Teeth.

It is easily seen that there are four kinds of teeth in the mouth even though the full number may not be there till the 20th year.

In the full set there are thirty-two, sixteen on each jaw, arranged as follows: In front are eight incisors with sharp edges, whose function is to cut the food, next on each side is one canine, or four in all, which are pointed and which the lower animals use for tearing food. In man they assist the incisors. Behind these on each

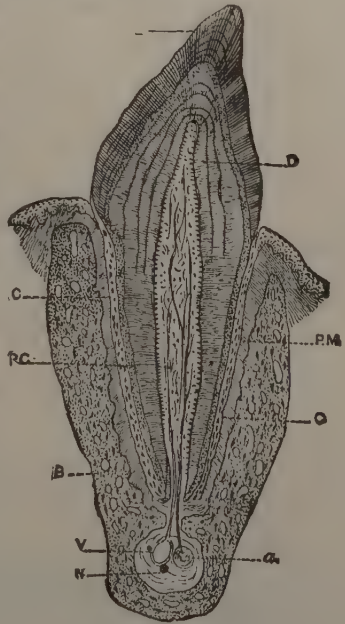


FIG. 116. Vertical section of a tooth in jaw. *E*, enamel; *D*, dentine; *P M*, peridontal membrane; *P C*, pulp cavity; *C*, cement; *B*, bone of lower jaw; *V*, vein; *A*, artery; *N*, nerve. (After Stirling.) From Kellogg.

side come two premolars and three molars, all with rough flat crowns and used to crush the food. The first or "milk" teeth lack the premolars and one set of molars hence number but twenty in all. The reason for having two sets is to allow for the growth of the jaw. Hence, if the first teeth are allowed to decay and are pulled too soon, the jaw never gets its proper shape and the later teeth are crowded and irregular. At the proper times the roots of the first teeth are absorbed and they make way easily for the permanent teeth and the jaw is developed into proper shape.

The numbers of teeth are often expressed in fractional form, and are easily remembered in this way. Beginning at the front in the middle of the jaw and putting the upper teeth above and the lower teeth below, we have the "dental formula" for the adult and first sets as follows:

	Incisors	Canines	Premolars	Molars
First set (20)	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{0}{0}$	$\frac{2}{2}$
Permanent set (32)	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{2}{2}$	$\frac{3}{3}$

The last pair of molars may not appear till about the 20th year and are therefore called the wisdom teeth, as one is supposed to have acquired some wisdom by that time.

Among other animals the teeth vary a great deal in size and number, but there is none that has a greater variety of kinds. Horses and cattle have molars greatly developed, cats and dogs have canines long and sharp, while rats and squirrels develop the incisors excessively for gnawing. Vegetable foods require broad grinding teeth, animal food needs sharp canines and shear-cutting premolars, while man, being adapted for a mixed diet, has all forms moderately developed. Chewing is one of the mechanical processes which prepares the food for chemical action by the digestive fluids.

Glands. Digestive fluids are secreted by organs called glands. A gland consists of a group of cells adapted for producing a fluid

secretion. These cells are developed on the inner walls of a cavity which usually opens into some other organ by way of a tube called a duct.

These cavities may be simple and very small, like the mucous glands that moisten all the digestive tract, or they may be very large and complex like the liver. In either case they must have a rich blood supply and nerves to control it and the action of the

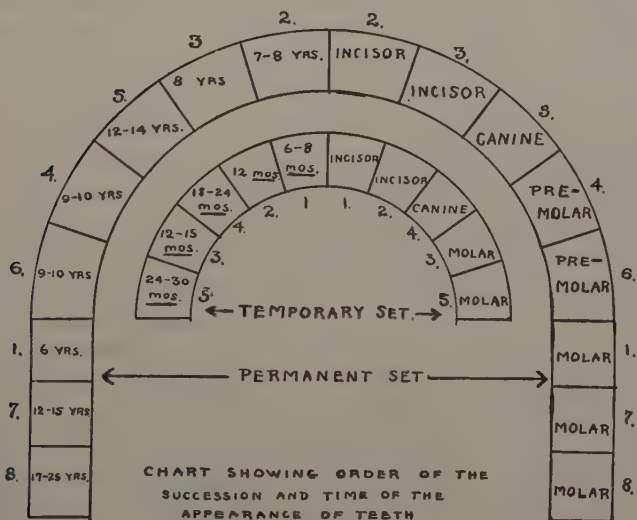


FIG. 117.

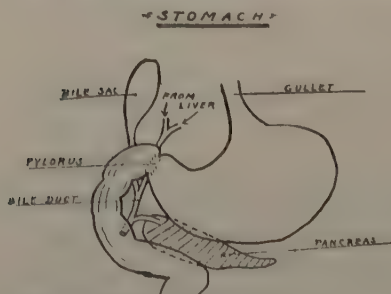
gland, as well. A gland, then, consists of the secreting cells, the gland cavity, the ducts, the blood and nerve supply.

Salivary Glands. The principal glands of the mouth are the salivary glands of which there are three pairs. The largest pair is located beneath the ear on each side of the head and the ducts open opposite the second upper molar. Inflammation of the glands causes the mumps. The sub-maxillary glands lie within the angles of the lower jaw and the sub-lingual pair are below the tongue, beneath the floor of the mouth; ducts from both pairs open under the middle of the tongue.

Saliva. Saliva is a thin, alkaline fluid containing the enzyme ptyalin, which changes starch to soluble sugar, but this action is slight, since the food remains so short a time in the mouth. However, the other functions of saliva make it important that it be thoroughly mixed with the food, since its presence in the stomach stimulates the gastric glands. It also permits foods to be tasted, since, only in solution will the food affect the nerves of this sense. Furthermore, saliva aids in chewing and is indispensable in swallowing food, so that its digestive function is only one of several, and the quantity secreted is much greater than one might suppose, being about three pints per day.

The steps of the digestion process in the mouth, then, are

1. Food mechanically crushed.
2. Food moistened for taste and swallowing.
3. Some starch changed to sugar.
4. *Very slight* absorption of sugar, water, salts.



Courtesy of Ginn and Company.

FIG. 118. From Hough and Sedgwick.

The Stomach. Passing from the mouth, the food enters the gullet, which at a distance of about nine inches enlarges into the stomach. This organ is located just beneath the diaphragm with the inlet at the left and close to the heart. Except when fully distended it is not the smooth, pear-shaped organ

usually pictured, but may be collapsed and empty, or almost any irregular shape, depending on its contents, and muscular movements.

Its function is very largely to store and finely divide the food. We usually eat at one time enough food to last for several hours. This food must be stored somewhere and the stomach provides the place. Also, chewing has only partly divided the food, so a second function of the stomach is to furnish the mechanical separa-

tion of the food particles by the churning motion of its muscular walls. The walls are also provided with millions of simple glands which secrete the gastric fluid at the rate of five to ten quarts per day.

Gastric Fluid. This gastric fluid contains hydrochloric acid and two ferments, rennin and pepsin. The rennin acts on the casein (milk proteid) changing it to curd, in which form it is more easily digested by other ferments.

(Note: rennin is used to "start" cheese and in "junket tablets," the latter made from calves' stomachs.)

Pepsin, acting only in the presence of an acid, changes some proteids to soluble peptones and also dissolves much connective tissue, thus exposing a greatly increased food surface for digestion in the intestine. Do not get the idea, that all or even a great deal of proteid food is completely digested in the stomach; in fact, as fast as they are finely divided, many proteids are discharged into the intestine where the pancreatic fluid completes the major part of proteid digestion.

The stomach, then, performs four functions, namely:

1. It acts as a storage for food.
2. It mechanically divides and separates food particles.
3. Rennin curdles casein.
4. Pepsin acts on some proteid and connective tissue.

Thus it is apparent that "stomach trouble" and digestive trouble *may* not mean the same thing, and despite the common idea, the bulk of digestive processes do not take place in the stomach but in the small intestine.

The food as it is discharged into the intestine is called chyme and consists of



FIG. 119. Section of pyloric glands from human stomach. *a*, mouth of gland leading into a long wide duct, *b*, into which open the terminal divisions; *c*, connective tissue of mucosa. After Piersee. See Kellogg.

1. The fats all unchanged.
2. Most of the carbohydrates.
3. A large portion of the proteids.
4. Some sugars, peptones and water, which were not absorbed in the stomach.

It is evident that, so far, the food has been mainly prepared *for* digestion rather than digested, a process that is chiefly accomplished in the small intestine.

The Intestine. The stomach connects with the small intestine by way of a muscular valve (the pylorus) which prevents the food from passing before it is thoroughly broken up in the stomach.



FIG. 120. Mucous membrane of the small intestine of the dog. *A*, artery; *B*, vein; *C*, capillaries; *D*, lacteals; *E*, glands of Lieberkühn; *Ep.*, epithelial tissue. After Cadiat. See Kellogg.

The intestine is the most important portion of the digestive tract, and consists of a coiled tube about twenty-five feet in length. The part next the stomach is about twenty feet long, about one inch in diameter and is called the *small intestine*, while the remaining five feet are over two inches in diameter and are called the *large intestine*.

The small intestine joins the large at the lower, right side of the abdomen, and at this point is the location of the appendix.

Inflammation of this organ is called appendicitis.

Adaptations for Increase of Surface. In order that both secretion of fluids and absorption of food may go on, much surface (for osmosis) is required.

For this increase of surface, the intestine is adapted in three ways:

1. Its great length and coiled position in the body.
2. Its inner lining projects in creases and folds.

3. The lining of the small intestine is thickly covered with microscopic projections (villi).

The villi are so fine and so numerous, that, under a lens, the intestinal lining looks like a piece of velvet. By these means the absorbing surface is increased five times, so that the total area of the intestine is not less than twenty-five square feet, or about twice as great as that of the skin.

Muscular Action. The intestinal walls are provided with layers of involuntary muscles which perform two functions by their contraction and expansion:

1. They mix and separate the food, thus constantly exposing it to digestive action.

2. They keep the food moving slowly through the digestive canal.

The efficiency of digestion and absorption depends as much upon these muscular movements as upon the chemical action of the digestive fluids, themselves. To provide the fluids for intestinal digestion there are three kinds of glands, (1) the intestinal glands, (2) the liver, (3) the pancreas.

Intestinal Glands. The intestinal glands are small, simple and very numerous, being located in the lining among the villi. They secrete a strongly alkaline fluid containing sodium carbonate and also enzymes that act on starches and sugars. This sodium carbonate (and other alkalis from the pancreatic fluid) combine with part of the fats, forming soaps, which are soluble and are thus absorbed.

The Liver. The liver is the largest gland in the body. It is located between the diaphragm and stomach, thus being the uppermost of the abdominal organs. The secretion of the liver is called *bile* and is a thick brown liquid, of which about one quart is produced daily. Bile has several important functions, as follows:

1. Bile is, itself, a waste substance, removed from the blood.
2. It aids in digestion and absorption of fats.
3. It stimulates the action of the intestine.
4. It tends to prevent decay of intestinal contents.

The chief digestive action of the bile is on the fats which it makes into a milk-like emulsion to be absorbed by the lacteals. If it is prevented from entering the intestine, over half of the fats eaten are not absorbed.

Another important function of the liver is the storage of excess carbohydrate food, in the form of *glycogen* or liver starch which the body may draw upon as a source of energy in emergencies. The liver, then, excretes waste, secretes a digestive fluid, and stores food.

Pancreas. Lying between the lower side of the stomach and the first fold of the intestine is the pancreas, whose secretion is by

far the most important in producing the chemical changes of digestion. The pancreatic fluid is strongly alkaline, and contains three enzymes: trypsin, amylopsin, and steapsin.

The trypsin resembles pepsin and completes the digestion of the proteids, changing them into soluble peptones. The amylopsin (like the ptyalin of saliva) changes starch to sugar, while the steapsin changes fats to fatty acids, soluble soaps, and glycerin, all of which are easily absorbed.

The pancreatic fluid thus completes the digestion of food after it has undergone the pre-

paratory steps of (1) cooking, (2) chewing, (3) salivary digestion, (4) gastric separation, (5) gastric digestion.

Absorption and Assimilation. The general purpose of digestion is to put the foods in a soluble form so that they may pass through the body's membranes by osmosis.

Absorption is the name given to the passage of digested food

ABSORPTION CHART.

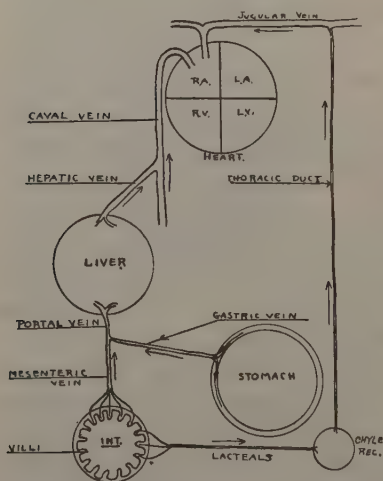


FIG. 121. Chart showing process of absorption.

materials from the digestive tract to the blood. However, absorption in a living animal is not merely a mechanical "soaking up" of prepared foods, but other changes take place, as the products of digestion enter the circulation.

Absorption may take place (1) directly into the blood capillaries which richly supply the walls of the stomach and intestine or (2) indirectly, by way of the lymph capillaries of the villi (lacteals) which eventually empty into the blood circulation also.

The capillaries of the gastric vein in the stomach walls absorb some water, a little digested proteid, and still less sugar, but the principal region of absorption is in the villi of the small intestine. Here the thin walls and enormous surface bring the digested foods close to the blood and lymph capillaries. Peptones, sugars and fatty acids, salts and water are passed into the blood stream, while the fats that have been emulsified are taken up by the lymph capillaries (lacteals) and carried by the lymphatic circulation to the thoracic duct and finally emptied into the general circulation, near the left jugular vein.

Assimilation. All the steps of digestion and absorption lead to the final process of assimilation, which either builds up the cells or supplies them with energy. For this purpose the blood carries the absorbed foods to the tissues. These foods pass as lymph (by osmosis) from the capillaries to the lymph spaces which surround every living cell, and there the assimilation occurs. Every cell of the body is practically an island, bathed on every side by lymph, which brings from the blood the digested food stuffs (and oxygen as well) and removes *to* the blood stream the waste matters produced by the cells' activities.

Nutrition. All these processes by which food is obtained, prepared, and built into tissues, are grouped together as nutrition and include:

1. Food-getting, selection, and preparation.
2. Digestion which mainly goes on in mouth, stomach, and intestines.
3. Absorption which occurs principally in the small intestine and stomach, by means of the blood capillaries and lacteals.

DIGESTION AND ABSORPTION

	Glands	Secretion	Ferments	Changes	Absorption
Mouth	Salivary Parotid Sub-lingual Sub-maxillary	Saliva (alkaline)	Ptyalin	Starch to sugar	
Gullet	Mucous	Mucus		Lubricant	
Stomach	Gastric Acid glands	Gastric fluid (acid) Hydrochloric acid	Pepsin Rennin	Proteids to peptones Coagulates casein Stimulates glands	Sugar Water Salts Peptones by capillaries of gastric vein
Intestine	Intestinal Liver Pancreas	Intestinal fluid Bile (alkaline) Pancreatic fluid (alkaline)	Invertin Trypsin Amylopsin Steapsin	Cane to grape sugar Emulsifies fats Proteid to peptones Starch to sugar Fats to fat acids and glycerin	Fats by lacteals Peptones Salts Sugars Water Fat acids by mesenteric capillaries

4. Assimilation which takes place wherever there is a living cell to be nourished.

Attention should be called to the important part played by osmosis in all these processes. It is concerned in the secretion of all digestive fluids; in the absorption of digested foods through the walls of the capillaries and lacteals, and in the passage of these same foods outward from the capillaries, as lymph, in assimilation.

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SUMMARY

Digestive Changes.

1. Making food soluble (for osmosis).
2. Changing food chemically (for assimilation).
3. Changes caused by
 - (a) Mechanical action of teeth and stomach.
 - (b) Chemical action of fluids, enzymes, ferments.

Digestive organs (cf. with other animals).

1. Mouth
2. Gullet and stomach.
3. Intestine.

Mouth.

Functions in digestion.

1. Mechanical (chewing).
2. Chemical (saliva).

Openings and organs.

1. Nasal openings (2), where, how protected, into what.
2. Eustachian tubes (2), where, how protected, into what.
3. Trachea (relation of epiglottis and tongue).
4. Gullet.
5. Hard and soft palate.
6. Tonsils, adenoids.

Tongue.

Structure, size, position in mouth.

Functions.

1. Taste (what use for taste, where located).
2. Aid in chewing. Aid in swallowing.
3. Cleaning teeth.
4. Speech.

Teeth.

Parts. Crown, neck, root (make diagram).

Structure.

1. Enamel (structure and function).
2. Dentine (structure and function).
3. Pulp region, nerves, and blood supply (why each).

Kinds:

Name	Structure	Number		Function
		1st	2nd	
Incisors		8	8	
Canines		4	4	
Premolars		0	8	
Molars		8	12	

Why two sets of teeth?

How does the change take place?

Special tooth adaptations in other animals,

Glands in general.**Definition.**

Parts, secreting cells and ducts, blood and nerve supply.

Various degrees of complexity.

Salivary glands.

1. Parotid (where located, duct opening), mumps.
2. Sub-maxillary.
3. Sub-lingual.

Saliva.

Composition, alkaline, watery, three pints daily, ptyalin.

Functions.

1. Aids in tasting food (solution).
2. Aids in swallowing.
3. Stimulates gastric glands (alkali *vs.* acid).
4. Ptyalin acts on starches slightly.

Digestive changes in the mouth.

1. Food mechanically crushed.
2. Moistened for taste and swallowing.

3. Some starch changed to sugar.
4. Slight absorption of water, sugar, etc.

Stomach.

Location.

Shape and size.

Functions.

1. Storage (why, what homologous organs).
2. Further separation of food particles.
3. Digestion of proteids by means of pepsin.
4. Coagulation of milk casein.

Gastric fluid.

1. From gastric (simple) glands, acid glands.
2. Amount, secretion aided by saliva if well mixed.
3. Composition

Hydrochloric acid

Pepsin

Function

Neutralize saliva, aid pepsin.

Proteid to peptone.

Dissolves connective tissue.

Exposes more surface for digestion.

Rennin

Coagulates milk proteid (casein).

Composition of chyme.

1. All fats unchanged.
2. Most carbohydrates (what exception?).
3. Much unchanged proteid.
4. Un-absorbed peptones, sugars, water, etc.

Intestine.

Pylorus, location and function.

Parts, small, large, colon, rectum, etc. (need not learn).

Appendix (lower right side).

Adaptations for increase of surface (for osmosis for absorption).

Length, 25 ft., much coiled.

Walls in-folded.

Villi (each with blood vessels and lacteals).

Surface increased five times, twice area of skin.

Muscular intestinal walls.

Muscles involuntary.

Keep food moving along.

Mix food with fluids and crush it.

Very important in digestion.

Glands.

Intestinal.

Small, simple, numerous, in the intestine wall lining.

Secretion, alkaline; soda carbonate; sugar ferment.

Function, saponify fats, act on sugar somewhat.

Liver.

Largest gland, uppermost in viscera, over stomach.

Bile, thick, brown, one quart daily.

Functions, waste.

Aids digestion and absorption of fats.

Stimulates intestinal action.

Antiseptic action.

General functions.

Excretion of waste.

Secretion of a digestive fluid.

Storage of sugar excess as glycogen (why?).

Pancreas, location.

Fluid, abundant, alkaline.

Composition.

Ferment	changes	[to]	soluble
Amylopsin	starch		sugar
Trypsin	proteid		peptone.
Steapsin	fats		fat acids, soaps, glycerin.

Preparatory steps in nutrition.

Food-getting, cooking, chewing.

Salivary digestion, gastric digestion (further breaking up).

Intestinal digestion (most important).

What processes are these steps a preparation for?

Absorption.

What is the general purpose of digestion?

What is the process on which absorption is based?

Absorption is the passage of food from digestive tract to blood.

May take place,

1. Directly into capillaries in stomach and intestine walls.
2. Via lymph capillaries (lacteals) in villi.

Absorbing organs	Where	What absorbed	Where emptied
Gastric capillaries	In stomach walls	Water Peptones Sugar	General circulation via gastric vein
Intestinal capillaries	In villi	Peptones Sugars Fatty acids Water, salts	General circulation via mesenteric vein
Lacteals or lymph capillaries	In villi	Emulsified fats	Thoracic duct to left jugular vein

Assimilation.

Meaning of word.

Definition.

Course of digested food.

Digestive organs to

Blood stream (osmosis).

Through capillary walls.

Into lymph spaces (osmosis).

Built into cell substance.

Blood transports food, etc., to tissues via capillaries.

Lymph transports foods, etc., to cells after leaving the capillaries.

Nutritive processes

Where performed.

1. Food-getting, preparation

Mouth, stomach, intestine.

2. Digestion.

3. Absorption.

Stomach, small intestine by capillaries and lacteals.

4. Assimilation.

In all living cells.

CHAPTER XXXIX

RESPIRATION

Vocabulary

Lymph, the liquid part of the blood, in contact with cells.

Pleural membranes, a double membrane covering lungs.

Intermittent, not continuous.

Depression, lowering.

Haemoglobin, the red, oxygen-carrying part of the blood.

Respiration is the process by which each cell of the body takes in oxygen and gives off carbon dioxide and water. It is tissue oxidation. The *breathing movements*, which renew the air in the lungs, and the *circulation* of blood, which is the means of transportation between lungs and tissues, are merely helps in the real process of respiration which goes on in every cell of the body.

Need of Circulation. These breathing and circulatory processes are required because of the distance of the living cells from the outer air and merely serve to keep the lymph supplied with oxygen and freed from waste. It is between the lymph and each living cell, that respiration actually goes on.

The organs generally associated with respiration, such as the lungs, trachea, etc., are really concerned with supplying oxygen to the blood and removing wastes. No more actual respiration (cell oxidation) goes on in the lungs, than in any other active tissue, but it *is* in the lungs that the haemoglobin of the blood receives its load of oxygen and unloads its carbon dioxide and water.

Development of Respiration. Respiration in the protozoa took place by direct contact of each cell with the air dissolved in the water. In the worms the blood circulated in the skin and obtained its oxygen direct from the air. In still higher forms, like crayfish or fish, gills were developed with great extent of surface to absorb

the dissolved oxygen in the water. Insects took their air directly into the tissues and blood by way of their numerous complicated air tubes and so got along with a simple circulation. In the birds and mammals this is reversed and the air comes to one place only

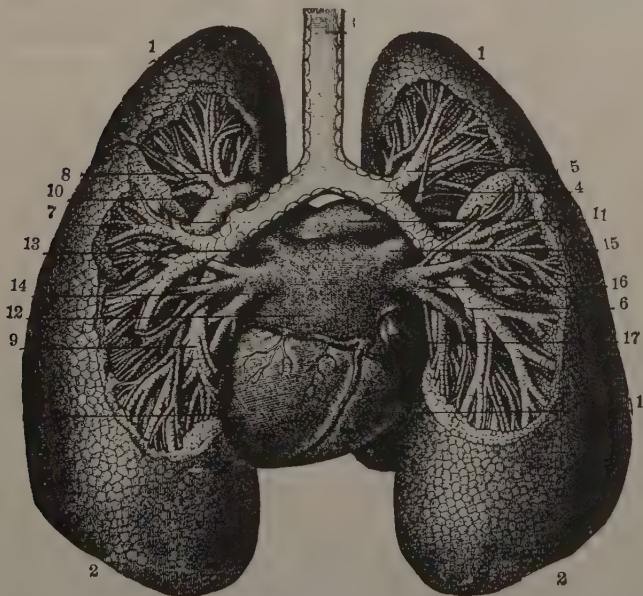


FIG. 122. Bronchi and lungs, posterior view, showing position of heart. 1, 1, summit of lungs; 2, 2, base of lungs; 3, trachea; 4, right bronchus; 5, branch to upper lobe of lung; 6, branch to lower lobe; 7, left bronchus; 8, branch to upper lobe; 9, branch to lower lobe; 10, left branch of pulmonary artery; 11, right branch; 12, left auricle of heart; 13, left superior pulmonary vein; 14, left inferior pulmonary vein; 15, right superior pulmonary vein; 16, right inferior pulmonary vein; 17, inferior vena cava; 18, left auricle of heart; 19, right ventricle. (After Sappey.) From Kellogg.

(the lungs), while a complex circulation carries the oxygen to all parts of the body.

Organs of Breathing. The organs concerned with breathing motions can be placed in two groups, (1) those concerned with holding and carrying the air, and (2) those which change the size of the chest cavity, causing the air to circulate.

Nose. The air system begins with the nose, which is adapted as an entrance for air,

- (1) By the hairs and moist mucus to catch dust.
- (2) By the sense of smell to guard against bad air.
- (3) By its long moist passages which warm and moisten the air.

The mouth was not intended as a breathing organ except in emergencies, and habitual mouth breathers lose all the advantages mentioned above.

Trachea. Passing from the nasal cavity to the back of the mouth, the air enters the trachea. This is a large tube which opens into the mouth at the back of the tongue, so that the food passes over it when we swallow. Its upper end is therefore protected by the base of the tongue and by a sort of self-acting lid (epiglottis) which closes when food is passing on its way to the gullet, which is further back in the mouth cavity. The enlarged upper end of the trachea is the larynx in which are situated the vocal (speech) organs, and which may be seen externally as the "Adam's apple." The walls of the trachea are supported by rings of cartilage, which hold it open for free passage of air.

With the hand on the larynx, swallow a mouthful of food and notice two things, (1) how it rises and contracts inward to meet the epiglottis, (2) how the very base of the tongue moves back and down over the opening. Both these movements are to allow the food to pass *over* the top of the trachea and *into* the gullet.

Bronchi and Air Cells. At its lower end the trachea divides into two branches (bronchi) extending to each lung, where they subdivide into countless minute bronchial tubes which finally terminate in very thin-walled, elastic air cells of which the lung tissue is largely made. Thus there is provided in one organ (the lungs) enough surface for air osmosis to supply (via blood) the needs of the millions of body cells that have no direct access to air.

The Lungs. The lungs fill all the body cavity from the shoulders to the diaphragm except the space occupied by the heart and blood vessels. They are very spongy, consisting mainly of the air tubes and cells and a very extensive network of blood vessels and capillaries, all held together by connective tissue and covered on the

outside by a double (pleural) membrane. Their shape is the same as the chest cavity, the upper part of which they completely fill. Between them is the heart and below is the diaphragm which is a muscular partition curving upward so that the lower lung surface is sharply concave. The pleural membrane that covers the lungs and lines the chest cavity is constantly moist and permits free motion of the lungs, within the chest, for breathing.

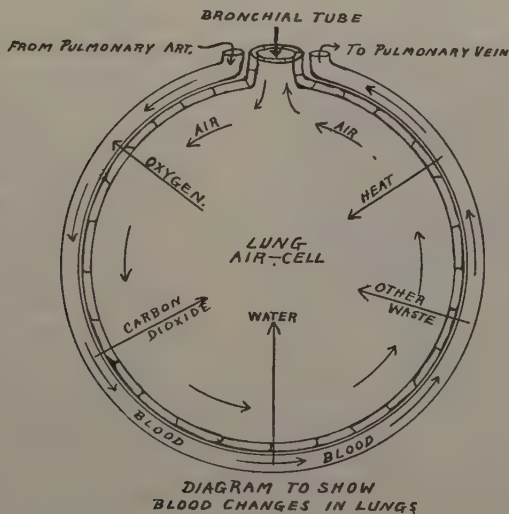


FIG. 123. Exchanges between blood and air in lungs. After Colton.

Pleurisy is an inflamed condition of these membranes which makes breathing very painful and difficult.

Blood Supply. The pulmonary artery brings the dark (de-oxygenated) blood to the lungs, where it divides into an extensive network of capillaries, completely surrounding each air cell. The thin walls of both cell and capillary make easy the osmotic exchange of oxygen from air to blood, and of carbon dioxide and water from blood to air, so that the pulmonary vein returns its blood to the heart, purified and laden with oxygen for the tissues.

Air Capacity. The total capacity of the lungs is about 350 cubic inches of which our ordinary breathing utilizes but about 30. By extra effort we can take in and force out an extra hundred or more, while there is about another hundred cubic inches which we cannot get out at any one breath. When we realize the great importance of oxygen to the tissues these facts ought to be an argument for fresh air, deep breathing, and loose clothing. We use little

RESPIRATION CHART.

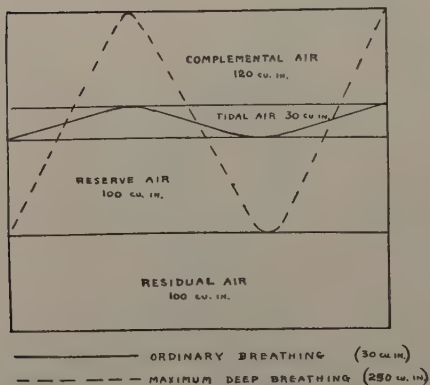


FIG. 124. Compare capacity utilized by ordinary breathing with that of deep breathing.

enough of our lungs, at best, so every effort ought to be made to increase their activity. The one-third of the air which cannot be forced out of the lungs provides for continuous osmosis. Breathing is an intermittent process but the blood's supply of air has to be continuous, hence the need for some air always in the lungs. A reason for deep breathing is to mix as much fresh air with this "residual air" as is possible at each breath.

Breathing Movements. The process of getting air into and out from the lungs is rather complicated and consists of two sets of operations, inspiration (breathing in) and expiration (breathing out) which we somewhat wrongly call the acts of respiration.

Inspiration: The Diaphragm. The chief breathing organ is the *diaphragm*, a muscle (not a mere partition) which extends across the body, curving upward, as a floor to the lung cavity. When its muscles contract it tends to pull down straighter across the body, thus giving the lungs more room, but compressing the abdominal organs beneath it at the same time.

Rib Muscles. Second in importance are muscles between the ribs which lift them up and outward, thus enlarging the lung cavity, but, which is more important, bending the elastic rib cartilages, which tend to spring the ribs back in place.

Air Pressure. The third important factor in inspiration is the pressure of the outside air which rushes in to occupy the extra space thus provided and by so doing, expands the elastic tissue of the lungs. Inspiration, then, consists of (1) depression of diaphragm and compression of abdominal organs, (2) raising the ribs and bending the rib cartilages, (3) air pressure, expanding the lung tissue.

Expiration. Expiration is merely the springing back of the organs that have been compressed by the movements of inspiration. It consists of the following steps: (1) the elastic reaction of the compressed abdominal organs, (2) the springing back of the rib cartilages, (3) the contraction of the elastic lung tissue.

All of these tend to make the lung capacity less and force out the air, against its own pressure. The change of position of the ribs, diaphragm and abdominal organs can be felt in our own bodies.

Rate of Breathing. This double process takes place from 16 to 24 times per minute, depending upon activity, position, and age.

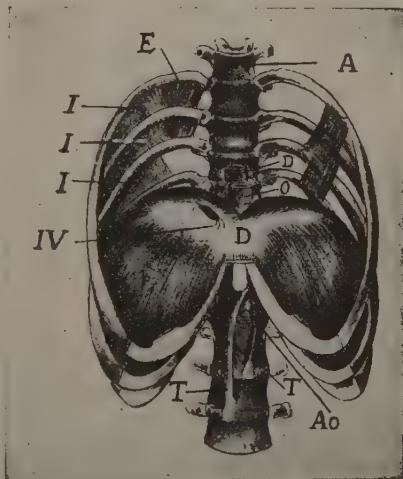


FIG. 125. Lower half of thorax with dorsal and lumbar vertebræ. *A*, sixth dorsal vertebra; *Ao*, aorta; *D*, (lower) diaphragm; *D*, (upper) aorta passing through diaphragm; *I*, intercostal muscles; *O*, œsophagus; *IV*, opening in diaphragm for vena cava ascending; *T T*, tendons of right and left crura attaching diaphragm to 3rd and 4th lumbar vertebræ. (After Allen Thomson.) From Kellogg.

The more oxygen the tissues need, the more rapidly the lungs have to operate to supply the blood with it, to be carried to the tissues.

Air Changes in Breathing. Air contains only about 20 per cent of oxygen. Of this, only about a quarter is absorbed in the lungs by the haemoglobin of the blood. In the circulation, the haemoglobin can give out only about one-half the oxygen it contains, so,

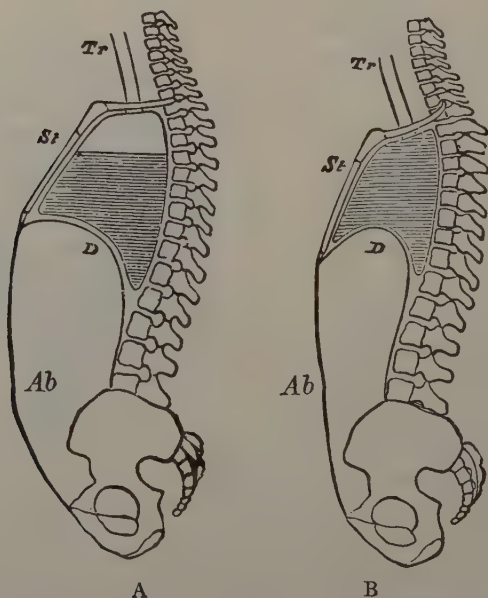


FIG. 126. Diagram to show the changes in the sternum, diaphragm, and abdominal wall in respiration. *A*, inspiration; *B*, expiration; *Tr*, trachea; *St*, sternum; *D*, diaphragm; *Ab*, abdominal wall. The shaded part is to indicate the stationary air. From Martin-Fitz.

unless we breath deeply and keep our breathing apparatus in healthy working order, the tissues may receive too little oxygen. Since oxidation (union of oxygen with tissue) is the only source of life energy, this matter is of very great importance.

Expired air loses about one-fourth of its oxygen, but receives 100 times as much carbon dioxide as it had when taken in, also a

large amount of water vapor and heat, together with a very little organic waste matter.

Ventilation. The fact that air in a "close" room becomes unfit to breathe, is due mainly to the excess moisture and heat, and not to the carbon dioxide, or lack of oxygen, as was formerly supposed.

The carbon dioxide in the expired air is produced by the oxygen from the lymph uniting with the carbon of the tissues. The water is produced by oxidation of their hydrogen, and the heat is the result of both oxidation processes. We use annually about 10,000 pounds of air (28.7 pounds per day) from which we take about 650 pounds of oxygen and give off about 730 pounds of carbon dioxide. We breathe out about 9 ounces of water every day, which would make half a pint in liquid form. These figures, while not worth remembering, will give some idea of the amount of work done by the respiratory organs and their importance to our life.

Proper ventilation is concerned, not only with supplying "fresh" air, but with the removal of water vapor, heat, and least of all, carbon dioxide. Here circulation of air in a room will often relieve breathing conditions, by lowering the body temperature and removing excess water vapor from the vicinity of the body. We usually have oxygen enough in any ordinary air supply, and seldom does the carbon dioxide cause trouble, but very often the temperature and amount of water vapor produce unpleasant and even dangerous results.

COLLATERAL READING

Physiology Textbook, Colton, pp. 105-137; *General Physiology*, Eddy, pp. 312-339; *Applied Physiology*, Overton, pp. 206-219; *Human Mechanism*, Hough and Sedgwick, pp. 162-176; *Human Body and Health*, Davison, pp. 132-162; *Studies in Physiology*, Peabody, pp. 209-231; *Human Body*, Martin, pp. 193-214; *Elementary Physiology*, Huxley, pp. 148-191; *High School Physiology*, Hughes, pp. 179-196;

SUMMARY

Definition, Respiration is oxidation in the tissues.

Aided by "breathing movements" (oxygen from air to blood).

Circulation (oxygen from blood, to lymph, to tissues).

Lungs supply osmotic surface for all cells in one place.

Circulation transports oxygen to interior tissues.

Development in lower animals.

Protozoa, each cell in contact with dissolved oxygen.

Worms, blood in contact with air in skin.

Crayfish, blood in contact with dissolved air (gills).

Insect, air brought to blood and tissues in tubes (tracheae).

Fish, blood in contact with dissolved air (gills).

Other vertebrates, blood aerated in lungs.

Organs of breathing.

1. Nose, adaptations, hairs to collect dust.

Smell, to detect bad air.

Moistening mucous membranes.

2. Trachea.

Connects mouth and lungs.

Opens back of tongue.

Stiffened by cartilage, larynx with vocal organs.

Protected by

Epiglottis.

Movements of tongue in swallowing.

Movements of larynx in swallowing.

Mucous glands and cilia.

3. Bronchi.

Two branches of trachea to lungs.

Each with many small branches.

Air cells at end of branches, vastly numerous.

4. Lungs.

Location. shape, boundaries.

Structure.

Air tubes and cells . . . surface for osmosis.

Capillaries . . . blood for transfer

Pleural membranes . . . moist for easy motion.

Blood supply.

Pulmonary arteries . . . dark, deoxygenated blood.

Pulmonary veins . . . lighter, oxygenated blood.

Capacity.

350 cu. in. total.

250 cu. in. possibly used.

30 cu. in. usually used in ordinary breath.

100 cu. in. residual air. Reason for "residual air."

Breathing movements

Inspiration (increases chest cavity).

- (1) Diaphragm contracts and lowers (*vs.* abdominal organs).
- (2) Rib muscles raise ribs (*vs.* elastic cartilage).
- (3) Air pressure expands cells (*vs.* elastic walls).

Expiration (decreases chest cavity).

- (1) Abdominal organs push diaphragm upward.
- (2) Rib cartilages spring back.
- (3) Lung cells contract.

Rate, 16-24 per minute, depends on age, activity, etc.

Air changes in breathing.

Air contains

<i>Before inspiration</i>		<i>After inspiration</i>
79 %	Nitrogen	79 %
20.96 %	Oxygen	16.02 %
.04 %	Carbon dioxide	4.38 %
traces	Water vapor	.60 %
little	Heat	much more.
none	Organic impurities	considerable.

Blood changes in lungs.

Just the reverse of the above.

Blood gains 4 to 5 % oxygen.

Blood loses about same amount carbon dioxide.

Blood loses water vapor, heat, organic waste.

Ventilation.

Large amount of air used.

Importance of oxidation.

Need for ventilation to supply oxygen.

to remove heat, water vapor, carbon dioxide.

CHAPTER XL

CIRCULATION

Vocabulary

Transportation, carrying from place to place.

Plasma, liquid portion of blood tissue.

Auricles, upper, receiving chambers of the heart.

Ventricles, lower, sending chambers of the heart.

The function of any circulatory system is transportation; the blood is the carrier, the blood vessels are the roads, and the heart is the motive power. Digested food is carried from the digestive organs to the tissues, oxygen from the lungs to the tissues, waste matters from the tissues to the lungs, skin, and kidneys, and internal secretions from their glands to places where they are used.

Development of Circulation. A circulatory system is not found in very simple animals like protozoa, sponges, and hydra, because they have so few cells that each can obtain its own food and oxygen and throw off its waste, without the need of a set of organs for carrying them. We do not find a transportation system within our own home, nor even in a small village, for each individual does his own carrying. In larger cities street railways are necessary, while to care for a whole state, numerous railroads and canals are required.

It is the same in animal structure. The simple forms have no circulatory transportation; in higher types there are simple circulatory organs (earthworm). In still more complicated organisms, a heart and blood vessels are required (crayfish), while in the vertebrates, especially birds and mammals with their very highly specialized organs, there is needed a very complete and complex transportation system, in order that each cell may be supplied.

Now we may carry our comparison between cell functions and life on Crusoe's island a step further and find another result of

THE FUNCTION OF THE BLOOD

TRANSPORTATION

Transportation of	From	To	For the Purpose of
Digested food	Digestive organs	Tissues	Supplying energy Building new tissues Rebuilding used tissues
Waste	Active tissues	Lungs Skin Kidneys	Removing harmful or useless substances, such as urea, carbon dioxide, water, etc.
Oxygen	Lungs	Tissues	Releasing energy by oxidation
Heat	Active tissue	Skin	Equalizing temperature at 98.5 deg.
Secretions	Glands	Various organs	Digestion, etc.

specialization. We will recall the likeness between the one-celled protozoan and Crusoe. He had to perform for himself all the functions of life, such as preparing his food, making his clothes and building his home. The higher forms of life are like small

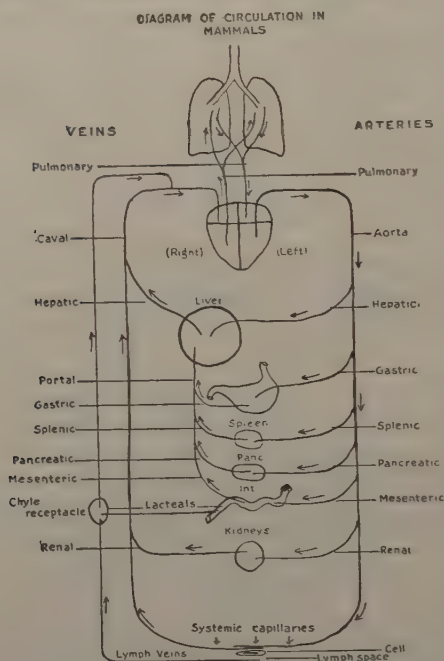


FIG. 127. Diagram showing circulation in mammals. Note the different routes by which the blood may make its circuit.

communities where one man may build the houses or another specialize in making clothes. This would correspond to the first steps in specialization, as shown by sponges, hydra, etc. As the communities grow, many men work together at one trade to supply all, and this would illustrate the grouping of specialized cells into tissues, each performing its function for the whole animal (earth worm). Then in larger communities the wants are more numerous, more groups of men specialize in different trades and supply others *at a distance* with their products. This is the stage represented by the higher animals, where a transportation (circulatory) system is required. In man this is accomplished by the blood, which is kept in motion by the heart, and flows through arteries, veins, and capillaries.

The Blood. The blood is a fluid tissue constituting about $\frac{1}{13}$ of the weight of the body. It consists of a liquid portion, called the plasma and solid portions, called the corpuscles or blood cells. *The plasma* constitutes $\frac{2}{3}$ the bulk of the blood and consists of

a liquid (serum) which carries the food and waste products, and a proteid substance (fibrinogen), which when exposed to air aids in forming a clot to stop bleeding. *The corpuscles* are of two sorts, red and white; the former much more numerous, thus giving the red color to the blood.

The red corpuscles are minute, disc-shaped, blood cells, so small that ten million can be spread on a square inch, yet so numerous

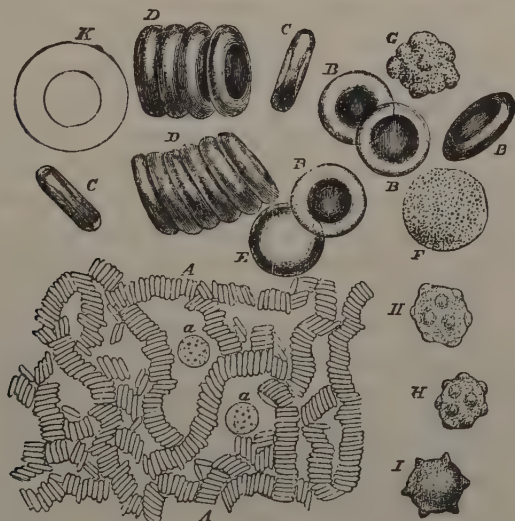


FIG. 128. Blood corpuscles. *A*, magnified about 400 diameters. The red corpuscles have arranged themselves in rouleaux; *a, a*, colorless corpuscles; *B*, red corpuscles more magnified and seen in focus; *E*, a red corpuscle slightly out of focus. Near the right hand top corner is a red corpuscle seen in three-quarter face, and at *C* one seen edgewise. *F, G, H, I*, white corpuscles highly magnified. From Martin-Fitz.

that there are enough in the average body to form a row four times around the equator. Their red color is due to a complex iron compound (haemoglobin) which carries oxygen from the lungs to the tissues. When laden with oxygen it is a bright red, but becomes darker when the oxygen is removed, causing the difference in color of the blood on going *to* and coming *from* the tissues.

The white corpuscles are really almost colorless and can change

their shape much like the amoeba. There are probably several kinds and their functions differ, but seem to be concerned in aiding the absorption of fats and in destroying disease germs in the blood. They are formed in the lymph glands. They have the power to penetrate the capillary walls and wander through the lymph spaces; they collect at wounds and points of infection and oppose the attack of disease germs.

Healing a Wound. In the healing of a cut there are several processes set at work by the blood. First, as the blood oozes out, fibrinogen is exposed to the air, hardens to fibrin, entangles the corpuscles, and the clot or scab forms. Then the blood supply is automatically increased to bring extra white corpuscles on guard to oppose infection; this causes the redness (inflammation). As the fibrin forms, it contracts, causing the puckering of a scar and as fast as new tissue is built, the clot or scab is shed. A slight scratch or blister often lets only the plasma through, while a "black and blue" bruise is in part due to breakage of capillary walls and consequent clotting of blood under the skin.

Changes in Composition of Blood. The composition of the blood is constantly changing as it receives and distributes its various burdens. This is shown in the following table.

CHANGES IN COMPOSITION OF BLOOD

	Blood loses	Blood receives
In all active tissues	Materials for growth, repair and energy	Wastes of oxidation Carbon dioxide and water Nitrogenous wastes
In walls of digestive organs	Materials for making digestive fluids and for growth, activity, and repair of the digestive organs	Digested nutrients
In the lungs	Carbon dioxide and water	Oxygen
In the kidneys and skin	Water and urea	Carbon dioxide, etc.

Probably the blood is actually purest when leaving the kidneys, though it is still dark colored, due to lack of oxygen. It is not correct to speak of "dark blood" as always being "impure blood."

The Heart. The heart is a hollow, cone-shaped muscle, located behind the breast bone, between the lungs, nearly on the center line of the body; the point is downward and lies between the fifth and sixth ribs a little to the left. Since the "beat" is strongest near the tip it has given the idea that the whole heart is on the left side, which is not true. The *heart* consists of two entirely separate halves, right and left, *each* of which consists of a thin-walled *auricle* and a thick muscular *ventricle*. The *auricles* act as reservoirs for the incoming blood and permit a steady flow and rapid filling of the ventricles. The *ventricles*, by alternate expansion and contraction, force the blood into the arteries and so around the body. Between each auricle and its ventricle are *valves* which allow blood to enter the ventricle but prevent its exit, except by the arteries, and at the base of each artery are valves preventing the blood from flowing back into the ventricles.

Action of Heart. The right auricle receives de-oxygenated blood from the veins through which it has been collected from the whole body. This passes through the valve into the right ventricle, which, when it contracts, forces it to the lungs, via the pulmonary arteries. In the lungs, the blood receives a new load of oxygen, unloads some carbon dioxide and water, and returns via the pulmonary veins to the left auricle. From here it passes through the valves into the left ventricle and is thence forced out through the aorta to all parts of the body. The ventricles contract and expand together so there are two waves of blood sent out at each beat, one to the lungs and one to the general circulation. While the ventricles are contracting and forcing *out* their blood, both auricles have been filling so there is no stop in the flow.

Rate of Beat. The rate of heart beat is normally 72 times per minute in man; 80, in women; much higher in young children and in very old persons, reaching the average at about twenty years of age. Naturally, the amount of blood needed is affected by exercise, temperature, food, excitement, pain, etc., and so all

these automatically change the rate of heart beat. When we run upstairs (a bad habit, by the way) we use more energy, hence oxidize more tissue, hence need more oxygen to be brought by the blood, and produce more waste, which must be carried off, and the heart has to work harder to meet this demand.

Blood Vessels. Arteries. All the vessels that carry blood away from the heart are *arteries* regardless of whether they carry red (oxygenated) or dark (de-oxygenated) blood. Arteries have elastic muscular walls, and very smooth linings. Their function is to assist and to regulate blood flow. Since they are elastic they expand when blood is forced into them, and as the valves prevent it from returning to the heart, their elastic contraction forces it to flow on through the arteries and exerts pressure clear to the capillaries.

If it were not for this elasticity, which is greatest in the large arteries, the circulation would be slow and unsteady and the arteries themselves in danger of bursting under the sudden strain, when the ventricles contract. In "hardening of the arteries" this elasticity is lost and produces serious and usually fatal results.

In general the arteries are protected by location beneath thick muscles, but at the wrist and neck some large ones come near the surface and this elastic wave of expansion can be felt, and is known as the pulse.

The muscles in the artery walls perform the very important function of regulating the amount of blood that reaches a given organ. By a very complicated system of nerve control, these muscles expand when more blood is required and contract when the supply is not needed.

Capillaries. As the arteries leave the heart they divide again and again, becoming smaller and thinner walled till they develop into microscopic tubes with a wall of only one layer of cells. These tiny blood vessels are the capillaries ("hair like") and are so numerous that they reach every living tissue of the body. Their large area and thin walls permit osmosis to go on readily and it is by way of osmosis from the capillaries that food actually reaches the body cells. Absorption of food in the digestive tract and ex-

cretion of waste from tissues in lungs, skin, and kidneys are also by way of these very important blood vessels.

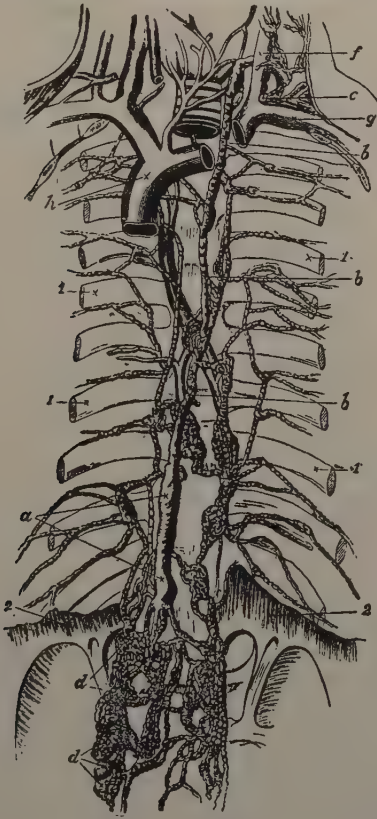


FIG. 129. The lymphatic vessels. The thoracic duct occupies the middle of the figure. It lies upon the spinal column, at the sides of which are seen portions of the ribs (1). *a*, the receptacle of the chyle; *b*, the trunk of the thoracic duct, opening at *c* into the junction of the left jugular (*f*) and subclavian (*g*) veins as they unite into the left innominate vein, which has been cut across to show the thoracic duct running behind it; *d*, lymphatic glands placed in the lumbar regions; *h*, the superior vena cava formed by the junction of the right and left innominate veins. From Martin-Fitz.

Veins. On leaving an organ the capillaries unite to form veins, which grow larger as they approach the heart, and always carry

blood *toward* this organ. Their walls are thinner than the arteries, having little elastic or muscular tissue, but many of the larger ones are provided with cup-like valves to prevent backward flow of blood. Veins are often just beneath the skin and can be easily seen on the back of the hand where the dark color of their blood is conspicuous; enlargements show the location of the valves. Veins have no pulse wave and the blood pressure is lower than in the arteries. Except for the pulmonary veins, their blood is dark (de-oxygenated) as compared with the redder, arterial blood. However, this is of little use in deciding whether a wound has cut a vein or artery, as on exposure to air, blood absorbs oxygen and brightens in color.

Bleeding from an artery, if large enough to be serious, is in pulse-like spurts, while the flow from veins is steady. This and the location of the wound are the best means of distinguishing the source of blood flow.

Lymph Circulation. A part of the blood plasma that diffuses through the capillary walls into the spaces between the cells does not return to the capillaries directly but is collected into the lymph capillaries.

These tiny tubes connect all the lymph spaces together and unite to form the lymph veins which eventually join to empty into the blood stream near the left jugular (neck) vein. Thus, a part of the plasma, instead of following the usual route (artery — capillary — vein) may return as follows, artery — capillary — lymph space — lymph capillary — lymph vein — true vein. It is in the form of this lymph that the blood actually nourishes the tissues and the lymphatic circulation is just as necessary as that of the blood as a whole.

Each cell of the body is practically an island surrounded by lymph. This lymph has passed, by osmosis, through the capillary walls, bearing in solution the digested food-stuffs from the alimentary tract, and oxygen from the lungs.

These the cell uses in its life activities and throws off carbon dioxide, water, and other wastes into the lymph, and thence into the blood of the vein capillaries.

White corpuscles may pass through the walls of the capillaries and thus get into the lymph spaces, from whence they may pass out with the returning lymph, by way of the lymph capillaries, to rejoin the blood, through the lymph system.

The lymph thus stands between the blood stream in the capillaries, and the living cells of the body. The blood leaves the heart

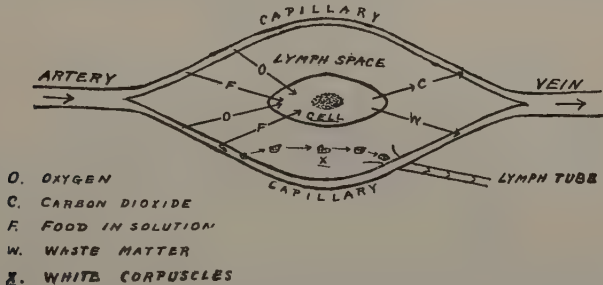


FIG. 130. Diagram to show relation between blood, lymph, and cells.

by one route, the arteries, and returns part way by two, namely the veins and the lymph system. These unite before reaching the heart again.

COLLATERAL READING

Civic Biology, Hunter, pp. 313-328; *Studies in Physiology*, Peabody, pp. 117-158; *Elementary Physiology*, Huxley, pp. 119-147; *Applied Physiology*, Overton, pp. 156-191; *Physiology for Beginners*, Foster and Shore, pp. 78-107; *General Physiology*, Eddy, pp. 159-203; *Physiology Textbook*, Colton, pp. 48-104; *Human Body and Health*, Davison, pp. 106-130; *High School Physiology*, Hughes, pp. 154-178.

SUMMARY

Function of circulatory system.

Transportation of food from digestive organs to tissues.

Transportation of oxygen from lungs to tissues.

Transportation of waste from tissues to lungs and kidneys.

Reasons for varying degrees of development.

Blood.

Composition. Plasma: (two-thirds bulk).

Serum, carrier of food and waste.

Fibrinogen, aids in forming clot.

Corpuscles: (one-third bulk).

Red, disc-shaped cells, minute, and numerous, contain haemoglobin (oxygen carrier).

White, amœboid, can penetrate tissues, destroy germs, help absorb fats.

Blood and the healing of wounds.

1. Fibrinogen exposed, fibrin forms clot.
2. White corpuscles brought by extra blood supply.
3. New tissue built and scar forms.

Changes in blood composition. (See tabulation in text.)

Heart.

Shape, hollow, cone-shaped muscle.

Location, between lungs, behind breast bone, point to left.

Structure.

Auricles, thin walled, act as reservoirs, cause steady flow.

Ventricles, thick-walled, muscular, propel the blood.

Valves, at base of arteries and between auricles and ventricles, prevent back flow of blood.

Action.

De-oxygenated blood from body, via caval veins flows to right auricle, right ventricle, pulmonary artery, lungs.

Oxygenated blood from lungs returns via pulmonary vein to left auricle, left ventricle, aorta, general body circulation.

Rate.

72-80 beats per minute.

Dependent on age, activity, state of mind, etc.

Arteries.

Carry blood *from* the heart.

Structure, smooth lining to permit easy blood flow.

Elastic tissue to allow for pressure and propel blood.

Muscular tissue to regulate blood supply.

Deeply placed for protection. Thick walled.

Veins.

Carry blood *toward* the heart.

Structure, smooth lining, pocket valves to prevent back flow.

Thin walled, and little elastic or muscle tissue.

Placed nearer the surface, no pulse wave.

Capillaries.

Connect arteries and veins.

Very thin, small, and numerous.

Provide surface for osmosis in nutrition, respiration, and excretion.

Lymph circulation.

Function.

Route.

CHAPTER XLI

EXCRETION

Vocabulary

Urine, the liquid excreted by the kidneys.

Urea, a nitrogenous substance in the urine, waste.

Duct, tube which carries excreted or secreted matter.

Excretion, throwing off of waste.

Secretion, production of useful substance by glands.

All the activities of the body require energy, whether in the muscles, nerves, or glands. Energy implies oxidation, and oxidation produces waste products which must be removed. The main wastes of the body are carbon dioxide and water and nitrogenous compounds (mainly urea) together with some mineral salts, chiefly sodium chloride (common salt).

Organs of Excretion. The most important organs of excretion are the kidneys and lungs; then come the intestine, liver, and last, the skin which has other more important functions.

Kidneys. The kidneys are bean-shaped glands located near the spine at the "small of the back." They are about two by four inches in size and are usually imbedded in fat. Their internal structure is too complicated for description here, but is perfectly fitted for removing from the blood, urea, uric acid, other nitrogen compounds, mineral salts, and water. Their blood supply is very large and under high pressure, which is important in removal of these wastes. As it leaves the kidneys in the renal veins, the blood is actually purer than anywhere else in the body though it may still be dark in color, due to lack of oxygen.

The ducts from the kidneys lead to the bladder where the urine (which is constantly being excreted) is stored. The amount of urine is usually about three pounds per day and the nitrogenous

wastes which it contains are of such character that if incompletely removed, very serious diseases are sure to result.

Exposure to cold, drinking large quantities of water, and excess of proteid food all tend to increase the amount of urine. As some of the waste matters are not very soluble, it is a good thing to

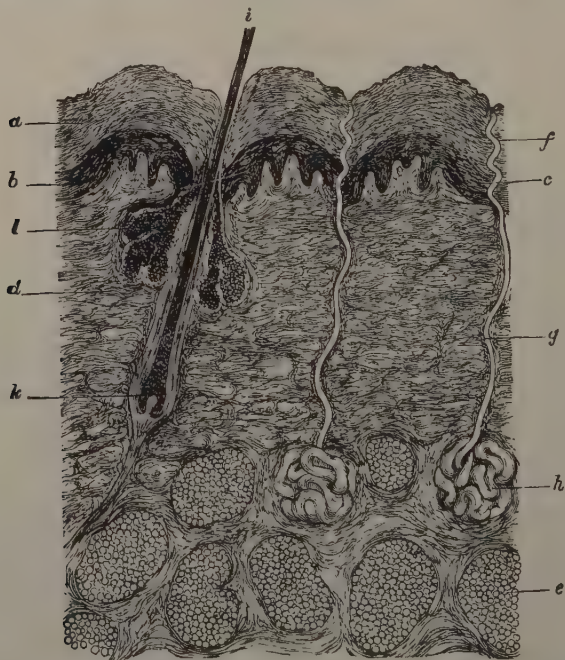


FIG. 131. Section perpendicularly through skin. *a*, epidermis; *b*, pigmentary layer of epidermis; *c*, papillary layer of dermis; *d*, dermis or true skin; *e*, fatty tissue; *f*, *g*, *h*, sweat glands and duct; *i*, *k*, hair with its follicle and papilla; *l*, sebaceous gland. (After Brubaker.) From Kellogg.

drink plenty of water to keep the kidneys well washed out. As a rule we drink too little rather than too much.

The Lungs. The lungs are used as organs of excretion as well as for the supply of oxygen, their wastes being carbon dioxide mainly, together with considerable water and very little nitrogenous compounds.

The Liver and Intestines. The liver and intestines are both concerned with the removal of bile, a part of which is waste matter, and the intestines also remove the unused food refuse, which, however is not strictly excretion.

The Skin. The skin excretes considerable water and only 1 per cent of solid matter, mainly salts, and a very little urea. The chief function of perspiration is to regulate the temperature of the body.

Structure. While not primarily an organ of excretion, the structure and functions of the skin may be discussed at this point. The human skin is a much thicker and more important organ than we usually suppose. When tanned into leather it resembles the pig-skin cover of a foot ball.

It consists of an outer portion (epidermis) composed of many layers of cells, the outer-most, dead, horny scales, the inner ones, more active and larger. Its function is mainly protective and the outer scales are constantly being rubbed off and replaced by new from beneath. Where subject to much friction or pressure the epidermis may grow to over a hundred cell layers in thickness, producing the familiar callouses of hands and feet.

Hair, nails, and color cells are developed from the epidermal layer in man. Scales, feathers, and claws are modified forms found in other animals.

Beneath the epidermis is a thicker layer (the dermis) consisting of tough fibrous connective tissue, richly supplied with blood and lymph vessels, nerves, sweat, and oil glands.

Functions of the Skin. These include:

1. Protection from germ attack and mechanical injury.
2. Protection of inner tissues from drying. The skin, aided by the oil glands, is nearly water proof, neither absorbing nor letting out moisture, except at the sweat pores.
3. It is the location of most of our nerves of touch.
4. Excretion of sweat as a waste matter.
5. Excretion of sweat to regulate the temperature of the body.

This last statement needs explanation. Birds and mammals are the only animals whose temperature does not change with

that of their surroundings. The rate of oxidation and hence the production of heat varies even more than the outside temperature and this means that a heat-regulating device is required.

Heat is required to evaporate water; therefore if moisture is excreted on the surface of the skin, the body's heat is taken up in evaporating it and consequently the skin is cooled. The blood supply to the skin is great, the surface exposed for evaporation is also large, and so by the use of the body heat to vaporize (dry off) the perspiration, the blood, and hence the whole body, is cooled.

The greater our activity or the warmer the surrounding air, the larger is the amount of perspiration, and hence the greater cooling effect.

A complex system of nerve control governs the blood supply and gland activity of the skin, so that, mainly by its means our temperature is kept at 98.5 degrees. The importance of this function of the skin is seen when we realize that a temperature of 8 or 10 degrees either above or below the normal is usually fatal.

COLLATERAL READING

Physiology Textbook, Colton, p. 381; *General Physiology*, Eddy, pp. 352-373; *Applied Physiology*, Overton, pp. 248-255; *Human Mechanism*, Hough and Sedgwick, pp. 177-186; *Human Body and Health*, Davison, pp. 175-190; *Studies in Physiology*, Peabody, pp. 232-252; *Human Body*, Martin, pp. 215-229; *Elementary Physiology*, Huxley, pp. 193-247; *High School Physiology*, Hughes, pp. 197-213.

SUMMARY

Waste, source, oxidation in tissues.

Kind, carbon dioxide, water, nitrogenous compounds, salts.

Organs of excretion.

1. Kidneys, location, small of back, near spine.
Size, two by four inches, bean shaped.
Blood supply large, high pressure.
Ducts connecting with bladder.
Remove water, urea, salts, etc. (3 lb. daily).
2. Lungs.
Remove carbon dioxide, water, little nitrogenous waste.
3. Liver and intestines.
Remove bile and unused food stuff.

4. Skin.

Removes water, salts, etc. (Not primarily excretory.)

Structure.

Epidermis, scale-like cells, loose.

Protective, callouses.

Modified as hair, nails, claws, horns, etc.

Dermis, fibrous cells.

Many blood and lymph capillaries.

Nerves, sweat and oil glands.

Functions.

Protection from germs.

Protection from injury.

Protection from drying of tissues.

Protection from water.

Sensation.

Excretion.

Temperature regulation.

Sweat excreted.

Evaporated by body heat.

Body therefore cooled.

CHAPTER XLII

THE NERVOUS SYSTEM

Vocabulary

Convolutions, irregular grooves in the surface of the cerebrum.

Voluntary, under control of the will.

Harmonize, to coördinate, to make to work together.

The brain is the one organ which in man is capable of greater development than any other animal. No amount of training will enable us to compete with the fish, bird, dog, or snake in speed, strength, locomotion, or keenness of sense. Practically every animal excels man in some way and the one thing that makes man their superior is his greater intelligence, which means greater brain development.

Despite this, we often devote more attention to other lines, in which we cannot hope for really useful success, and leave to very indifferent care the training of our one source of superiority.

While we cannot deal with the structure of the brain in detail the need of some controlling organ to regulate the complicated functions of any animal's body is very apparent and we must needs take up its study, if only very briefly.

Structure. The brain consists of three general regions, the cerebrum, the cerebellum, and the spinal bulb. Connected with it are the spinal cord and nerves which together with the brain compose the *central nervous system*.

Cerebrum. The cerebrum constitutes about nine-tenths of the brain; it occupies the upper part of the skull and is divided into two halves or hemispheres. Its surface is deeply folded in irregular grooves (convolutions) and consists of gray nerve cells while internally the bulk of its tissue is made up of white nerve fibers.

The vastly complex structure by which each cell is cross connected to thousands of others, the tree-like branching of the nerves, the grouping in larger fibers and passage from one part to another of the brain and spinal cord, all will have to be omitted. We know that it is the most complicated organ in the world but we are far from a complete understanding of its structure, much less its mode of operation.

Experiment and disease have shown that the cerebrum is the center of intelligence, thought, memory, will, and the emotions. It is the region of conscious sensation, by which we perceive all that goes on about us, and in it arise the impulses which produce all our voluntary motions.

Cerebellum. The cerebellum is situated behind and below the cerebrum, is much smaller, is not divided, and has shallower and more regular convolutions. Its function is mainly to regulate and harmonize (coördinate) muscular action. This is very essential. When we run, or skate, or walk, or swim, or throw a ball, we use nearly all of the five hundred muscles of our body. Each muscle fiber is controlled by a nerve; each nerve impulse must reach its muscle at the proper instant. When we stop to analyze the simplest act and think how many muscles are made to work to-

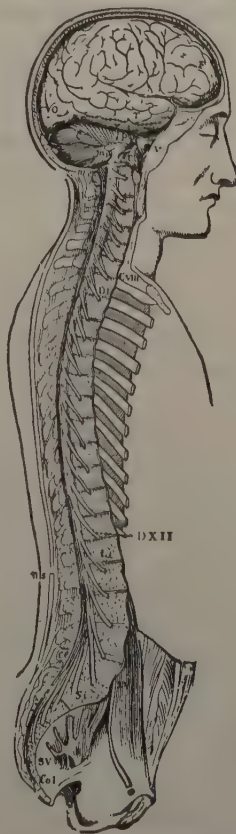


FIG. 132. Central organs of the nervous system. *F, T, O*, frontal, temporal and occipital lobes of the cerebrum; *C*, cerebellum; *P*, pons varolii; *mo*, medulla oblongata; *ms-ms*, upper and lower limits of the spinal cord; *CVII*, 8th cervical nerve; *DXII*, 12th dorsal nerve. (Quain after Bourguery.) From Kellogg.

gether in perfect harmony, we realize how important is this co-ordination of muscular action by the cerebellum. Without it, though the cerebrum might originate the impulse to do a certain act, no regulated useful motion could result.

Medulla. The spinal bulb (medulla) is really an enlargement of the spinal cord but is within the skull and closely attached to the cerebellum. It is about the size of a walnut and is located at the extreme base of the brain.

The spinal bulb is the center of control of respiration, circulation, secretion, movements of digestive organs and of swallowing, as well as other similar automatic and unconscious activities. Naturally, death follows injury to this vitally important part of the brain, though severe damage to the other parts may not be fatal.

Spinal Cord. The spinal cord extends from the medulla through the protective bony arch of each vertebra, down almost the whole length of the spine, and from it branch the nerves that supply all parts of the body, except those which spring from the brain directly. The spinal cord is not merely a large nerve trunk, however, but is the center of many involuntary muscular actions (reflex actions) of the body and limbs. If we touch a hot stove, we do not have to *think* to remove our hands. If something comes near an eye, we do not have to depend on the *brain* to close the eye. Voluntary action would take too long and injury would result before the brain could have time to act, so all such reflex actions are centered in the spinal cord and operate automatically but not *unconsciously* as do the motions of the internal organs controlled by the medulla.

The spinal cord, then, has two functions:

- (1) A connecting trunk between brain and other nerves.
- (2) The center of reflex action.

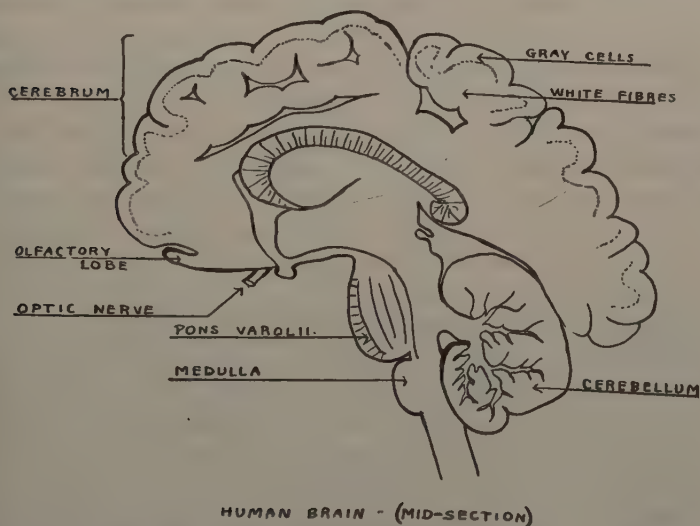
Sympathetic System. On each side of the spinal column but *inside* the body cavity are two rows of nerve ganglia which are connected with each other and with the brain and spinal cord.

From this double nerve chain extend branches to most of the internal organs and to other ganglia located in the chest and ab-

domen. The largest of these sympathetic ganglia is the solar plexus, located just below the diaphragm, another is near the heart, and a third low down in the abdomen.

The operation of the sympathetic system is not well understood but it certainly controls the secretion of glands, the regulation of blood supply in arteries, heart action, and probably many other internal activities of which we are not conscious, but without which we could not live.

The "sympathetic system" has nothing to do with "sympathy"



HUMAN BRAIN - (MID-SECTION)

FIG. 133. Diagram of mid-section of human brain showing position of important parts.

in its usual sense, but is so named since it seems to keep the *in-voluntary* internal organs working in harmony, much as the cerebellum coördinates the action of the voluntary organs.

It appears that our nervous system is capable of controlling several kinds of action, for example:

1. Voluntary actions, originating in the cerebrum and co-ordinated by cerebellum.

2. Involuntary and unconscious action of internal organs controlled by medulla and sympathetic system.

3. Involuntary *but conscious* reflex actions controlled by the spinal cord.

4. Actions, at first voluntary, that have become reflex (automatic) by habit, like learning to walk.

Habit Formation. To accomplish a given act or thought, the nerve impulse has to connect up various parts of the brain. At first this is done with difficulty and we say we are "learning to read" or to ride a bicycle or play a piano. However, repeated voluntary acts soon make their proper nerve connections easier, as if a path were being worn in the brain along which the impulses travel with greater and greater ease.

If we continue doing a certain act or thinking a certain way often enough, it becomes the easiest way to act or to think, and we say we have "acquired the habit." If we look up the derivation of that word, *habit*, we find that it comes from "*habeo*," meaning to have or hold. So instead of our getting the habit, as we say, the habit has "got" us.

It is a serious thing to think of, for our whole life is a complex mass of habits, — things which hold us, — acts and thoughts that do themselves, and which we "just can't help." How careful we should be that those brain paths are the best arranged so that habits of thought shall be prompt and accurate. How watchful we should be that only good and helpful paths be followed, for, whether we wish it or not, the habit will get and hold us. It is only too true that "As a man thinketh . . . so is he."

"The hell to be endured hereafter, of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters in the wrong way. Could the young but realize how soon they will become mere walking bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by

saying, 'I won't count this time!' Well! he may not count it, and a kind Heaven may not count it; but it is being counted none the less. Down among his nerve cells and fibers the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is, in strict scientific literalness, wiped out. Of course this has its good side as well as its bad one. As we become permanent drunkards by so many separate drinks, so we become saints in the moral, and authorities in the practical and scientific, spheres by so many separate acts and hours of work. Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he *keep faithfully busy* each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning, to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out." — James, *Psychology*.

COLLATERAL READING

Physiology Textbook, Colton, pp. 254-298; *General Physiology*, Eddy, pp. 382-428; *Applied Physiology*, Overton, pp. 266-275; *Human Mechanism*, Hough and Sedgwick, pp. 266-288; *Human Body and Health*, Davison, pp. 215-236; *Studies in Physiology*, Peabody, pp. 253-290; *Human Body*, Martin, pp. 230-262; *Elementary Physiology*, Huxley, pp. 475-551; *High School Physiology*, Hughes, pp. 214-234.

SUMMARY

Reason for Special Training of the Brain.

General Function, Control.

Parts of Nervous System.

1. Brain.

Cerebrum, location, size, shape, surface, character of substance.

Functions, intelligence, will, thought, sensation, voluntary motion.

Cerebellum, location, size, surface.

Function, muscular coördination, for voluntary acts.

Medulla (spinal bulb), location, size.

Function, control of respiration, circulation, etc.

2. Spinal cord, location (cf. spinal column).

Functions, nerve connection.

Reflex control.

3. Nerves, to receive sensation, and transmit motion impulses.
4. Sympathetic system, location.
 Structure, plexuses (solar, cardiac, abdominal).
 Function, coördinates involuntary actions.

Nervous system controls	by means of	examples
1. Voluntary actions	Cerebrum Cerebellum	
2. Involuntary actions (un-conscious)	Medulla Sympathetic system	
3. Involuntary reflex (con-conscious)	Spinal cord	
4. Automatic actions	Whole system	

CHAPTER XLIII

THE SENSE ORGANS

Vocabulary

Irritability, response of simple organs to environment.

Papillae, minute projections supplied with nerve endings.

Pigment, color substance.

Concentrate, to bring to one point, to focus.

Competent, able.

The chief function of the nervous system mentioned in the previous chapter was that of *control*. It has another equally important use, namely to keep us in touch with our surroundings by what we call sensation.

Irritability. All living things respond more or less to their environment. Plants react to light, moisture, contact, and gravitation, and thus have a very simple sort of sensation, usually called "irritability." These responses are sufficient for their needs, as our experiments have shown, and enable plants to reach food and water supplies, to turn leaves toward light, to climb by means of tendrils and to perform certain movements concerned in pollination and seed dispersal.

Touch. Even the simplest animals are affected by actual contact with surroundings. The amoeba recoils from hard or hot particles, absorbs food when in contact with it, and thus may be said to exhibit a primitive sense of touch.

In higher forms, the whole body surface possesses this sense more or less. It is often especially developed in tentacles, hairs, or papillae in various animals. In man the sense of touch is common to all parts of the skin, especially the finger tips, forehead, and tongue. The human skin also possesses special nerves that receive temperature, pressure, and pain sensations. If we gently touch

different places on the back of the hand with a pencil point, some spots will feel warm and others cold, due to the presence or absence of these temperature nerves.

Taste. All animals seem to prefer some foods and reject others. We have to assume a sort of taste sense to account for this. To be tasted, a substance has to be in solution and in contact with certain organs near the mouth. The mouth parts, palpi and tongue are the usual taste organs, and in man the different parts of the tongue are sensitive to different tastes. The back part responds only to bitter, the tip to sweet, the sides to sour, and the whole surface to salty flavors. Much that we attribute to taste is really due to the sense of smell; if eyes and nose are closed one can hardly distinguish between an apple, onion, or raw potato. Taste enables animals to judge of foods, stimulates the flow of digestive fluids and in aquatic forms may give information as to their location in the water.

Smell. Both touch and taste require the substance to be in actual contact if it is perceived. Smell reaches a little farther away and enables animals to detect substances in the form of vapor or dilute solution, even though at a distance.

The organs of smell are sometimes hairs, often antennae, while vertebrates have some sort of a "nose." They are usually near the food-getting organs, and in air breathers, are associated with the inlet to the lungs. Primarily the sense of smell is used to judge of food and air supply but in many cases it is also useful in finding food, detecting enemies, and locating mates. It is little developed in aquatic animals but very keen in insects, carnivora, and most ungulates.

Hearing. In contrast to the three senses mentioned above hearing puts us in touch with our surroundings through the medium of sound waves conveyed by air or water. This brings within range of our consciousness things at a much greater distance and is the chief avenue of communication among all higher animals, most of which possess some form of sound-producing organs.

The simplest ears in worms, molluscs, and crustaceans consist of mere sacs lined with nerve endings. In insects the sacs are

covered with a tympanum or drum membrane, and possibly the antennae are sensitive to sound vibrations as well. Ear organs may be located on legs, abdomen, antennae, and head in various animals.

Structure of the Human Ear. The vertebrate ear is a wonderfully complicated organ, consisting of an external ear which opens

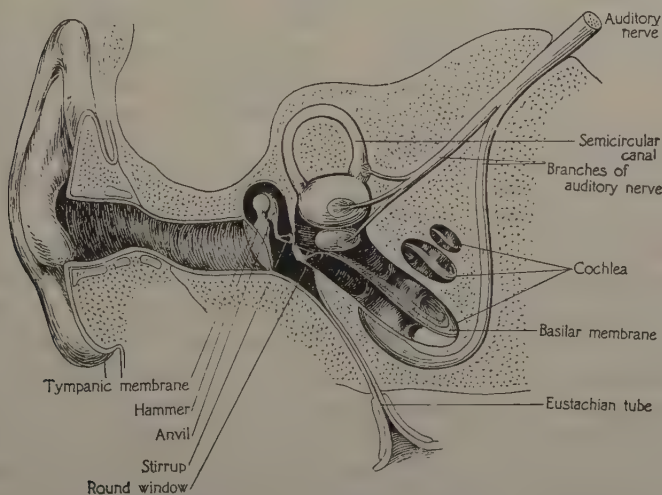


FIG. 134. Semi-diagrammatic section through the right ear.
(After Martin.) From Kellogg.

into an auditory canal embedded in the skull. This canal is closed at its inner end by the tympanic membrane, which separates it from the middle ear.

The middle ear connects with the throat by way of the eustachian tube which serves to equalize the air pressure on both sides of the drum and thus prevents breakage, while permitting free vibration. Across the middle ear extends a chain of tiny bones which connects the tympanic membrane with a somewhat similar membrane in the wall of the inner ear.

The internal ear consists of two general parts. The cochlea is a cavity in the skull shaped like a snail shell, filled with a liquid and

lined with a complicated set of nerve endings, which receive the sound impressions. The semicircular canals, three in number, are little loop-shaped tubes each at right angles to the other, and have to do with maintaining the balance of the body.

How We Hear. When a person speaks to you, he starts certain air waves which are gathered in by the external ear, and conveyed to the tympanum, which is thus made to vibrate. By means of the bones of the middle ear, this vibration is communicated to the fluid in the inner ear, and this in turn acts upon the nerve endings of the cochlea. This disturbance of the nerve endings is transmitted to the brain by way of the auditory nerves and we hear the sound of words.

The human ear can distinguish vibrations varying from sixteen to forty thousand per second, but we have reason to believe that insects can hear sounds of higher pitch.

Care of the Ears. Fortunately this delicate and important organ is deeply imbedded in the skull where little harm can reach it, but care must be observed not to injure the tympanum by probing with hard implements, ear spoons, etc., when trying to clean the ear. In this connection it has been said that one ought never to explore their ears with anything sharper than their elbow.

Ear wax has a useful function in keeping out dirt and insects, and excess can be properly removed by ordinary washing. Foreign bodies should be washed out and never removed by "poking" with hairpins and other implements. Water which enters the ears in diving does no harm, and can easily be shaken out.

Ear ache or a discharge from the ear may indicate a serious condition and should have immediate attention from a physician. The brain and ear cavities are very close together at one point, so that inflammation of the ear may reach the brain with fatal results.

Temporary deafness may be caused by inflammation of the eustachian tubes as a result of a cold. Permanent deafness may be caused by a blow on the ear bursting the tympanum, or by disease of the middle or inner ear. It is always a serious matter and should never be treated by advertising quack doctors, whose

only skill consists in their ability to separate their victims from their money.

Sight. Plants and the lower animals respond to light but can hardly be said to "see." The sensation of sight reaches us by way of waves in the ether, which are studied more fully in Physics. These light waves reach us from vast distances and at enormous speed and put us in touch with a wider extent of our surroundings than all the other senses combined. This fact, and its relation to our other activities, make sight the most valued of all our senses. Yet there is hardly an organ that we abuse more than we do our eyes.

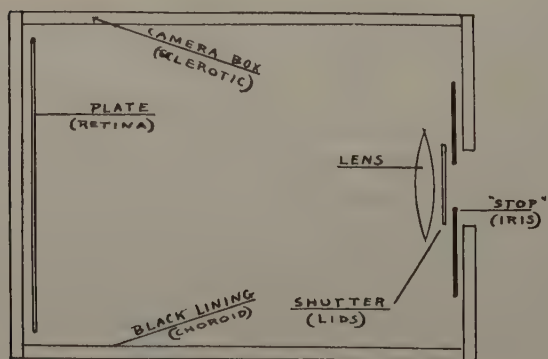
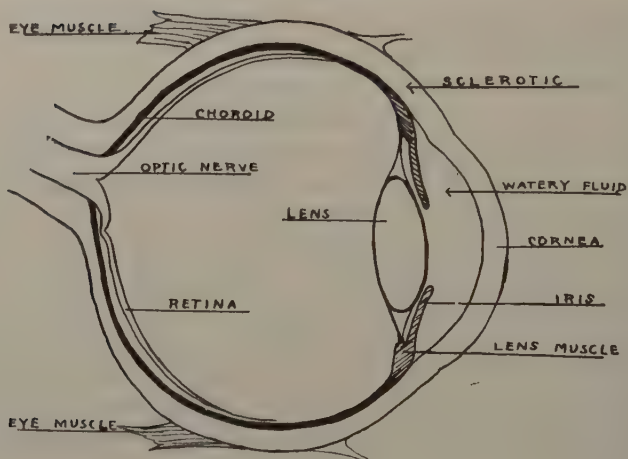
The simplest eyes were mere colored spots connected with special nerves to absorb light and tell its direction. Now we have lenses developed to concentrate light upon these sensitive pigment spots, muscles to adjust both lens and eye and various devices to protect the whole.

Structure of the Human Eye. The eye is almost spherical in shape, flattened a little from front to rear. The wall of the eye-ball consists of three layers. The outer one is tough and white, called the sclerotic coat, and shows in front as the "white of the eye." The anterior surface of the sclerotic bulges out a little, and becomes transparent in the circular region called the cornea.

The second coat, called the choroid, is richly supplied with blood vessels and pigment (color) cells which prevent reflection of light inside the eye-ball. This coat shows in front as the iris or "color" of the eye. The iris is provided with muscles which regulate the size of the center opening, the pupil, according to the amount of light.

The inner layer is the most delicate and complicated part of the eye and is called the retina. It is really the expanded end of the optic nerve and connects directly with the brain. It also has a dark pigment and though only $\frac{1}{80}$ of an inch in thickness, it consists of at least seven distinct layers of cells which help in receiving the impression which we call sight.

The lens of the eye is located just behind the iris and is connected to the choroid by delicate muscles which can change its thickness, to adjust for near or distant vision.



THE EYE AND THE CAMERA

FIG. 135.

The space in front between the lens and cornea is filled with a watery fluid and the ball of the eye is occupied by a jelly-like transparent substance, which keeps the eye in shape.

How We See. Light waves from an object pass through the cornea to the lens which concentrates (focuses) them upon the

retina as you would focus a picture on the film of your camera. The iris controls the amount of light entering the eye and the lens muscles change its shape so that the picture on the retina may be sharp and clear. The retina is affected by the light that falls upon it and the impression is carried to the brain by the optic nerve, as sight.

Protection of the Eye. Obviously, the eye cannot be buried in the skull for protection, like the ear, but it is well guarded none the less. The bony socket, walled in by the forehead, nose and cheek ward off any but direct blows. The pad of fat on which it rests saves it from jar or pressure. The eyebrows keep out perspiration and the lids and lashes protect from dust. Tear secretion constantly washes the front surface and a complicated set of reflex actions helps us to ward off most injuries to this important sense organ.

The Living Camera. The eye is often compared to a camera and there are so many resemblances, that it may be helpful to study this table of comparisons.

Part of eye	corresponding to	Part of Camera
Ball		Camera box
Lens		Lens
Lids		Shutter
Iris		Stops or diaphragm
Pupil		Lens opening
Lens muscles		Focusing devices
Black pigment		Black lining
Retina		Plate or film

In making this comparison it must always be borne in mind that there are also fundamental differences. The eye is alive, the camera is not. The eye produces a sensation which reaches the brain, the camera makes a picture. The eye focuses by changing the *shape* of the lens, the camera, by changing its distance from the film.

Defects of the Eye. The care of the eye is dealt with in the chapter on hygiene, but it is well to remember that seldom are they perfectly normal and frequent examination by a competent physician is the only sure way of preserving their health. Below are tabulated some of the common conditions and their causes, but only an expert can determine the exact kind of lens or method of treatment which will remedy the defect.

Condition	Defect of eye	Remedy
Near sight	Eye ball too long	Concave lens glasses
Far sight	Eye ball too short	Convex lens glasses
Astigmatism	Irregularity in shape of lens, or cornea	Special cylinder lens glasses
Old age	Loss of lens adjustment resulting in far sight	Convex lens glasses

COLLATERAL READING

Animal Studies, Jordan, Kellogg and Heath, pp. 371-386; *Animal Life*, Jordan and Kellogg, pp. 224-239; *Physiology Textbook*, Colton, pp. 284-300; *General Physiology*, Eddy, pp. 436-485; *Applied Physiology*, Overton, pp. 268-275; *The Human Mechanism*, Hough and Sedgwick, pp. 244-265; *The Human Body and Health*, Davison, pp. 237-258; *Studies in Physiology*, Peabody, pp. 291-320; *The Human Body*, Martin, pp. 263-294; *Elementary Physiology*, Huxley, pp. 367-457; *High School Physiology*, Hughes, pp. 239-260.

SUMMARY

Response to environment.

1. Irritability.
2. Touch.
3. Taste.
4. Smell.
5. Hearing

(a) Structure of ear.

Outer ear, auditory canal and lobe.

Middle ear, bones, eustachian tube.

Inner ear, cochlea and nerve endings, semicircular canals.

COMPARISON OF SENSATIONS

Sense	Organs	Medium	Uses	Examples	Range
Touch	Surface Skin, hairs Tentacles Papillae	Contact with solids	Recognition of food and surroundings	Most widely distrib- uted Simplest	Actual contact
Taste	Palpi Mouth parts Tongue	Contact with sub- stances in solution	To judge food and surroundings	Less general	Solution in contact
Smell	Antennae Hairs Nose	Vapor particles	To judge of food and air, locate enemies and mates	Keen in the carnivora, ungulates and in- sects	Semi distant con- tact
Hearing	Sac and nerve endings. Ears, antennae, hairs, tympanum	Air waves	Communication Warning Implies sound mak- ing organs	Sacs in polyp, worm, mollusc, and crus- tacea Tympanum in insects and vertebrates	Distant Voice <i>vs.</i> speech
Sight	Pigment spots Retina, lens, nerves	Ether waves	Most valuable in all above uses	Compound and simple eyes	Vast distance

(b) How we hear.

(c) Care of ears.

6. Sight.

(a) Structure of eyes.

Coats,

Sclerotic, white, thick, protective, cornea in front.

Choroid, blood vessels and pigment, iris in front.

Retina, dark, complicated, receives impressions.

Lens, convex, adjustable by muscles.

(b) How we see.

(c) Protection of the eye.

(d) The living camera.

(e) Defects of the eye.

CHAPTER XLIV

BIOLOGY AND HEALTH

Vocabulary

Excessive, more than necessary.

Mastication, chewing.

Flexible, easily bent.

Vagaries, whims.

One of the chief reasons for the study of biology is to learn how to properly care for our own body and to maintain both it and its surroundings in healthful condition.

The science which deals with the care and health of the body is called *hygiene*; that which deals with keeping its environment healthful is called *sanitation*.

A great many foolish "rules of hygiene" have been devised but if we will apply our general knowledge of biology, mixed with a goodly amount of common sense (which is not common), we can construct our own. We know the amount and kinds of foods required, and can judge the evils of improper or excessive eating. We know the need and process of digestion and can reach our own conclusion as to chewing food, care of teeth, removal of waste, etc.

We have learned the use of oxidation and can see the reason for correct posture, clothing, and exercise, which affect breathing. In this way a sensible human being ought to be able to apply biology to his own life and it is much better than trying to memorize any set of rules, however wise they may be.

In the same way, sanitation means the knowledge of biology as applied to food and water supply, infectious diseases, ventilation, sewerage, clean streets, etc.

In our elementary work we have studied both these subjects to some extent. This chapter will merely attempt to summarize a few of the principal facts.

Health is the natural condition of the body, and yet, how many have never been sick, or are now in absolutely perfect health. We must remember that any lack of health is due to some biologic mistake. While we can probably never know enough to absolutely avoid disease certainly our study of biology ought to help us to escape those troubles whose causes we *do* know. If we lived as well as we knew how, everybody would be much stronger, healthier, and happier. It is to call attention to some of the simpler applications of biology to health, that this chapter is written.

Hygiene of the Muscles. A great deal is being done with regard to proper muscular exercise and it is well to understand some of the reasons for the importance of this matter. The least important result is one most often mentioned, namely the fact that exercises *strengthen* the muscles used. This is true but the following results are much more important to health.

1. Exercise increases oxidation, from three to ten times; this means that greater bodily energy is liberated.

2. From this it follows that the heat-regulating and excretory organs are trained to their work.

3. Exercise withdraws the blood from the internal organs, to the muscles and so relieves the tendency to over-supply and congestion; this is shown by the "healthy color" of the complexion due to the blood supply in the outer muscles; a very pale skin usually indicates poor health.

4. Only by proper exercise do the heart and arteries receive necessary training in supplying the blood to the tissues.

5. In the same way, exercise aids in the use and health of the lungs and breathing organs.

6. Motion of the muscles is one of the chief causes of lymph flow and we know that upon the lymph circulation depends the nutrition of the tissues.

No rules can be given as to special kinds of exercise, since different people need different forms, just as we need different amounts of food, but in general it may be said that any exercise should bring about the results mentioned above, and should not be such as to endanger or overstrain any part of the body.

Proper exercise should

1. Be vigorous, continuous, and reasonably prolonged. For

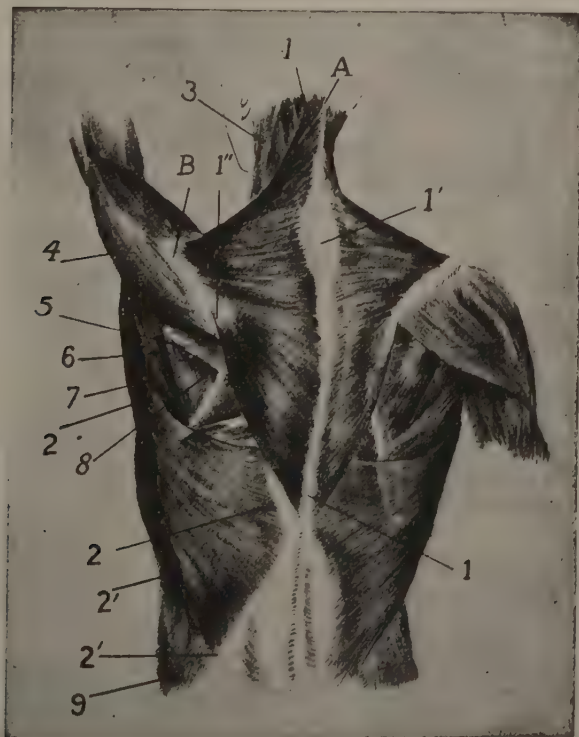


FIG. 136. Superficial muscles of trunk, shoulder and back viewed from behind. A, external occipital protuberance; 1-1, trapezius muscles; 1' oval tendon between right and left trapezius; 1' insertion of trapezius; B, summit of shoulder (acromion); 2-2', lateral muscle and insertion; 3, sterno-mastoid; 4, deltoid; 5, infraspinatus; 6, teres minor; 7, teres major; 8, rhomboideus major; 9, part of external oblique muscle of abdomen. (After Allen Thomson.) From Kellogg.

For example a brisk walk is one of the best of exercises, while a short stroll or saunter does little good, though often mistaken for "exercise."

2. Useful exercise should use the *body muscles* as well as arms and legs: walking, swimming, and throwing are good examples.

3. Exercise should cause full, deep breathing and preferably should be in the open air. Loose clothing and erect position necessarily follow.

4. Exercise should be *varied* and should occupy the *mind* as well as the body; any movements, however excellent, lose much if they are not enjoyed while being performed. This is the objection to many really beneficial "systems of exercise" which become very distasteful because of lack of interest.

Hygiene of Digestion. For the general study of foods refer to Chapter 37. The following is a summary of facts explained there:

1. The amount and kind of food should be adjusted to the work of the body.

2. The "balance" of the ration should be maintained.

3. The food should be clean and properly prepared.

4. Usually the heartiest meal should come after the day's work and should be preceded by a brief rest. Only when the brain or muscles are not working, can the digestive organs get proper supply of blood.

5. Eating between meals is usually a bad practice, especially in case of sweet foods, as it prevents proper desire for, and digestion of, the solid food which the body requires.

6. Water in abundance should be used both between and at meals, but not to "wash down" unchewed food. It does not "dilute the gastric fluid" but passes quickly from the stomach and digestion is aided rather than hindered.

7. It is unnecessary to dwell upon the importance of thorough chewing. The smaller the food particles, the greater the surface exposed for digestion and the less burden is put upon the stomach. The starch digestion in the mouth may not be very extensive, but thorough mastication prevents over-eating and too rapid eating, both of which produce more indigestion than all other causes put together. "Leave the table hungry" is a good rule. Americans eat too much, particularly of proteid foods, a habit which is both unhealthful and expensive.

8. Proper care of the teeth is necessary if food is to be thoroughly chewed. It is sufficient to remember that tooth decay is a bacterial process, that the warmth and moisture of the mouth make ideal conditions for bacterial growth, and that perfect cleanliness is our only means of protection. This suggests frequent careful brushing, use of antiseptic tooth washes, and a visit to a dentist at least twice a year "whether you need it or not."

9. Violent exercise, severe study, worry, or any mental or physical activity, at or near meal-times interferes with proper digestion.

10. Regular attention must be given to the removal of waste from the intestine, as a long series of illnesses can be traced to lack of care in this regard.

Hygiene of Respiration. We have learned the use which the body makes of oxygen in releasing the energy in our foods and keeping us alive and active. Naturally, proper breathing is required if this process is to go on in a healthful way.

We need to train our breathing muscles, because few of us know how to breathe, even though we use the expression "natural as breathing."

Deep breathing means using more lung tissue, getting more oxygen, and developing the diaphragm and rib muscles, properly.

We cannot use *all* our lung capacity at once, but should use all we can. We train the other muscles for less important uses; why not train our breathing muscles for the race of life?

Erect position and comfortable clothing are necessary if we are to breathe properly.

The nose was made for breathing, not the mouth (see Chap. 39) and any disease or growth which interferes with nose breathing should be removed.

Ventilation. Deep breathing will do little good if the air breathed is bad: this means attention to ventilation. Proper ventilation should secure

1. A sufficient amount of air in proportion to the number concerned

2. A slight continuous movement of air through the whole room, without perceptible draughts.

3. A sufficient degree of heat to keep the body in comfort, usually 68 to 70 degrees.

4. A moderate amount of moisture in the air so that it will neither interfere with evaporation from the skin, nor yet tend to dry it.

5. The removal of chemical impurities and odors; the amount of CO_2 should not exceed .06 per cent.

6. The removal of excess moisture which is especially great in crowded rooms.

“ Fresh air ” is not necessarily cold air as some people seem to think, though for sleeping rooms, the temperature should be lower than in living quarters. Extreme cold is not an advantage even in sleeping rooms, except in cases of tuberculosis, and many people subject themselves to dangerous exposure in this way. Air should be pure, cool, and abundant, but there is no virtue in extreme coldness.

Dust Removal. Dust carries bacteria, hence air should be as free from it as possible. This means replacing the broom and feather duster by the vacuum cleaner and oiled dust cloth. Rugs and hard-wood floors should take the place of the permanent carpet. Smooth walls, simple furniture, and few hangings offer less opportunity for the accumulation of dust. Sprinkling, oiling, and flushing the streets attain the same result for out-door dust.

Hygiene of the Eyes. The human eye is such a delicate and necessary structure that its care should be emphasized, but just because it is so complicated, no rules can be made which will properly safeguard this most valuable sense organ. The one safe procedure is to have the eyes examined by a competent expert from time to time, even if no defect appears to be developing.

Reading in poor light, or at evening when the light is gradually failing, is a common error. Almost as bad is the use of too bright light directly facing the eyes, or reflected from too shiny paper in books. Long continued use of the eyes on very fine print or sewing causes severe strain, just as in continued use of any other organ

Actual defects in structure or, more often, over use under poor conditions, produce "eye strain" and from this result headache, sleeplessness, and nervous troubles of serious nature, in addition to the damage to the eye itself. Common sense in their use, immediate rest when any feeling of fatigue is caused, and prompt advice from an expert, are the only rules for the care of our eyes.

Hygiene of Bathing. Washing is primarily to remove dirt. Dirt is objectionable for two reasons: it is offensive to refined people and it often carries disease germs.

Washing to "keep the pores open" is not a true reason, because the skin excretes but little waste, and the pores open quickly, even in the dirtiest skin, when perspiration is required for heat regulation.

However, there is a stronger argument for a daily *cold* bath, because it gives the skin practice in adjusting itself to sudden changes of temperature similar to those it encounters in every day exposure. The cold shower or sponge bath, if followed by brisk rubbing, causes the skin arteries to contract, and then expand again, as evidenced by the glow of the skin.

This is precisely what the body should do when exposed to sudden chill of any sort, and if trained by frequent cold bathing, the arteries will be ready to regulate the blood supply and no cold or congestion will result.

Neither cold bathing nor swimming should be done within at least an hour after meals, as the blood is needed to absorb the food, and should not be diverted to the skin. The bath should not be so cold, nor the swim so long continued, as to cause a permanent chill or prevent the warm reaction when the body is rubbed dry.

The cold bath is primarily a means of prevention of "colds" and all that they lead to; it should be taken daily in the morning, immediately upon rising. The warm bath is solely a means of cleansing the skin, should not be taken every day and only just before retiring, when precautions to prevent chill can be observed. A very hot bath should be taken only by physician's orders.

Hygiene of the Teeth. The importance of dental hygiene has been mentioned before but cannot be too much emphasized. Conditions in the mouth are ideal for the growth of bacteria which cause decay. Warmth and moisture are sure to be present, and unless great care is observed, particles of food will remain for the bacteria to feed upon.

It is not a pleasant experiment, but if the teeth be scraped with the finger nail and the odor of the substance removed observed, we will have no doubt that decay is going on. The total area of possible tooth infection is equal to that of two standard petri dishes (over twelve square inches).

The decay of food between the teeth destroys the protective enamel and the dentine then goes rapidly. The immediate results are bad breath, pain, and loss of teeth. Fully as serious are the secondary consequences of poor chewing: indigestion, pus diseases from infected gums, rheumatism, and nervous disorders. Tonsils, throat, ears, and even the lungs may be infected from the teeth.

The first or "milk teeth" deserve as great care as the permanent set. If they decay and are removed too soon the jaws and face never attain their proper shape and proportion, and the later teeth will not fit properly together.

Hygiene of the Feet. With the possible exception of the eye, no human organ has been worse abused than the foot. We crowd our feet into air-tight leather boxes, bend the toes together, lift the heel high off the ground and then wonder why we suffer from corns, bunions, and fallen arches. Proper shoes should have their inner edges nearly straight, heel low and broad, toe with room enough so that the toes can separate and "wiggle." The uppers should be flexible, as porous as possible, and not too tightly laced. The arch of a normal bare foot should not touch the floor on the inner edge and the shoe should be so shaped as to support this upward curve. The selection of shoes should be guided by the expert advice of a doctor or trained fitter and not be governed by the vagaries of style or the demands of fashion. Feet were made to walk on, not to look at. In walking the feet should be carried

forward with the toes straight ahead, not turned out as is commonly done. "Toeing out" is as abnormal as "toeing in" but is so common that it is less noticed.

Posture. *Standing.* The human animal is not as yet completely adapted to his erect position. This makes especial care necessary to achieve a healthful posture both in walking and sitting.

The head should be held up in a natural position with chin drawn back, not stiffly, but with the feeling that you are pushing your hat up. The shoulders may be either sloping or square by nature, but need never be rounded forward. If we still walked on all fours they would be pushed back by our weight; now we reverse the process and carry weight upon them. This makes it especially needful that we hold our shoulders back and our chest up to give proper play to the lungs.

The abdominal organs tend to press each other down and forward. This has to be met, partly by raising the chest and partly by strengthening the front body walls, to hold them in place.

Sitting. In our modern life we do so much work sitting down, especially reading and writing, that particular care has to be exercised in regard to this. The shoulders are apt to be bent forward, the spine twisted sidewise, and the weight brought too high up by sliding down in the chair. All these habits cramp the breathing and digestive organs and may produce permanent deformity or bad health. The obvious remedy is to sit back in the chair, with shoulders up, and lean forward only from the hips.

Hygiene of the Nerves. Man has reached the stage where mental activity takes the place of physical exertion and there is consequent danger of one-sided development.

Mental fatigue is just as real as muscular fatigue. The brain should not be forced to work when it is already tired nor when the energy of the body has been used in hard physical labor.

Mental hygiene is just as important as physical hygiene. A well-trained brain, developed by proper exercise, is vastly more valuable than powerful muscles and needs even greater care in its development. True education means just this training and developing of a skillful brain, rather than merely storing the mind with various

kinds of information. Accumulation of facts is a very important function of the brain, it is true, but is not to be compared with developing it to observe, think, and really reason.

Sleep is the period of rest from nerve activity, relaxation of muscles, repair of waste, and growth of new tissue. Because children are growing as well as using tissue by their intense activity they need more sleep than the adult. While seven to nine hours sleep will do for most grown-ups, children ought to have from ten to twelve hours.

The following are rules of individual hygiene as summarized from the Yale Lectures on Hygiene by Professor Irving Fisher.

Air. Keep outdoors as much as possible.

Breathe through the nose, not through the mouth.

When indoors, have the air as fresh as possible —

(a) By having aired the room before occupancy.

(b) By having it continuously ventilated while occupied.

Not only purity, but coolness, dryness, and motion of the air, if not very extreme, are advantageous. Air in heated houses in winter is usually too dry, and many be humidified with advantage.

Clothing should be sufficient to keep one warm. The minimum that will secure this result is the best. The more porous your clothes, the more the skin is educated to perform its functions with increasingly less need for protection. Take an air bath as often and as long as possible.

Water. Take a daily water bath, not only for cleanliness, but for skin gymnastics. A cold bath is better for this purpose than a hot bath. A short hot followed by a short cold bath is still better. In fatigue, a very hot bath lasting only half a minute is good.

A neutral bath, beginning at 97° or 98° , dropping not more than 5° , and continued 15 minutes or more is an excellent means of resting the nerves.

Be sure that the water you drink is free from dangerous germs and impurities. "Soft" water is better than "hard" water. Ice water should be avoided unless sipped and warmed in the mouth. Ice may contain *spores* of germs even when germs themselves are killed by cold.

Cool water drinking, including especially a glass half an hour before breakfast and on retiring, is a remedy for constipation.

Food. Teeth should be brushed *thoroughly* several times a day, and floss silk used between the teeth. Persistence in keeping the mouth clean is not only good for the teeth, but for the stomach.

Masticate all food up to the point of involuntary swallowing, with the attention on the taste, not on the mastication. Food should simply be chewed and relished, with no thought of swallowing. There should be no more effort to prevent than to force swallowing. It will be found that if you attend only to the agreeable task of extracting the flavors of your food, Nature will take care of the swallowing, and this will become, like breathing, involuntary. The more you rely on instinct, the more normal, stronger, and surer the instinct becomes. The instinct by which most people eat is perverted through the "hurry habit" and the use of abnormal foods. Thorough mastication takes time, and therefore one must not feel hurried at meals if the best results are to be secured.

Sip liquids, except water, and mix with saliva as though they were solids.

The stopping point for eating should be at the *earliest* moment when one is really satisfied.

The frequency of meals and time to take them should be so adjusted that no meal is taken before a previous meal is well out of the way, in order that the stomach may have had time to rest and prepare new juices. Normal appetite is a good guide in this respect. One's best sleep is on an empty stomach. Food puts one to sleep by diverting blood from the head, but disturbs sleep later. Water, however, or even fruit may be taken before retiring without injury.

An exclusive diet is usually unsafe. Even foods which are not ideally the best are probably needed when no better are available, or when the appetite especially calls for them.

The following is a very tentative list of foods in the order of excellence for general purposes, subject, of course, to their palatability at the time eaten: fruits, nuts, grains (including bread), butter, buttermilk, salt in small quantities, cream, milk, potatoes,

and other vegetables (if fiber is rejected), eggs, custards, digested cheese (such as cottage cheese, cream cheeses, pineapple cheese, Swiss cheese, Cheddar cheese, etc.), curds, whey, vegetables, if fiber is swallowed, sugar, chocolate, and cocoa, putrefactive cheeses (such as Limburger, Rochefort, etc.), fish, shellfish, game, poultry, meats, liver, sweetbreads, meat soups, beef tea, bouillon, meat extracts, tea and coffee, condiments (other than salt), and alcohol. None of these should be absolutely excluded, unless it be the last half dozen, which, with tobacco, are best dispensed with for reasons of health. Instead of excluding specific food, it is safer to follow appetite, merely giving the benefit of the doubt between two foods, equally palatable, to the one higher in the list. In general, hard and dry foods are preferable to soft and wet foods. Use some raw foods — nuts, fruits, salads, milk, or other — daily.

The amount of proteid required is much less than ordinarily consumed. Through thorough mastication the amount of proteid is automatically reduced to its proper level.

The sudden or artificial reduction in proteid to the ideal standard is apt to produce temporarily a "sour stomach," unless fats be used abundantly.

To balance each meal is of the utmost importance. When one can trust the appetite, it is an almost infallible method of balancing but some knowledge of foods will help. The aim, however, should always be — and this cannot be too often repeated — to educate the appetite to the point of deciding all these questions automatically.

Exercise and Rest. The hygienic life should have a proper balance between rest and exercise of various kinds, physical and mental. Generally every muscle in the body should be exercised daily.

Muscular exercise should hold the attention, and call into play will power. Exercise should be enjoyed as play, not endured as work.

The most beneficial exercises are those which stimulate the action of the heart and lungs, such as rapid walking, running, hill climbing, and swimming.

The exercise of the abdominal muscles is the most important in order to give tone to those muscles and thus aid the portal circulation. For the same reason erect posture, not only in standing, but in sitting, is important. Support the hollow of the back by a cushion or otherwise.

Exercise should always be limited by fatigue, which brings with it fatigue poisons. This is nature's signal when to rest. If one's use of diet and air is proper, the fatigue point will be much further off than otherwise.

One should learn to relax when not in activity. The habit produces rest, even between exertions very close together, and enables one to continue to repeat those exertions for a much longer time than otherwise. The habit of lying down when tired is a good one.

The same principles apply to mental rest. Avoid worry, anger, fear, excitement, hate, jealousy, grief, and all depressing or abnormal mental states. This is to be done not so much by repressing these feelings as by *dropping* or ignoring them — that is, by diverting and controlling the attention. The secret of mental hygiene lies in the direction of attention. One's mental attitude, from a hygienic standpoint, ought to be optimistic and serene, and this attitude should be striven for not only in order to produce health, but as an end in itself, for which, in fact, even health is properly sought. In addition, the individual should, of course, avoid infection, poisons, and other dangers.

Occasional physical examination by a *competent* medical examiner is advisable. In case of illness, competent medical treatment should be sought.

Finally, the duty of the individual does not end with personal hygiene. He should take part in the movements to secure better public hygiene in city, state, and nation. He has a selfish as well as an altruistic motive to do this. His air, water, and food depend on health legislation and administration.

COLLATERAL READING

School Hygiene, Shaw, entire; *Outlines of Practical Sanitation*, Bashore, see index; *The Health of the City*, Godfrey, see index; *Handbook of Health*,

Hutchinson, entire; *Preventable Diseases*, Hutchinson, entire; *Civics and Health*, Allen, see index; *Primer of Sanitation*, Ritchie, entire; *Good Health*, Jewett, entire; *Mind and Work*, Gulick, entire; *The Human Body and Health*, Davison, see index; *The Human Mechanism*, Hough and Sedgwick, pp. 289-540; *General Hygiene*, Overton, see index; *Practical Biology*, Smallwood, pp. 233-258; *Applied Biology*, Bigelow, pp. 525-560.

SUMMARY

Hygiene, care and health of body (exercise, breathing, food, eyes, etc.)

Sanitation, providing healthful surroundings (water supply, drainage, infection, ventilation).

1. Hygiene of muscles.

Exercise, increases oxidation.

Trains heat regulating and excretion.

Prevents internal congestion.

Trains heart and arteries.

Trains breathing organs.

Aids lymph circulation.

Exercise should be vigorous, use body muscles, cause deep breathing, occupy mind.

2. Hygiene of digestion.

Food should be

(1) Adapted to body needs.

(2) Balanced ration.

(3) Clean and well prepared.

(4) Eaten when rested.

(5) Eaten at regular times.

(6) Accompanied by water.

(7) Thoroughly chewed.

Errors affecting digestion.

(1) Rapid eating.

(2) Insufficient chewing.

(3) Washing down food.

(4) Eating too much.

(5) Not getting rid of waste.

Care of teeth.

(1) Frequent cleaning.

(2) Use of tooth wash or powder.

(3) Consult dentist often.

3. Respiration.

(1) Train your breathing muscles, ribs and diaphragm.

(2) Loose clothing for free action.

(3) Erect position to allow lung action.

(4) Pure air supply; not necessarily cold.

(5) Air free from dust.

4. Ventilation.
 - Essentials for proper ventilation.
 - Dust removal.
5. Care of the eyes.
 - Have frequent examinations.
 - Provide proper light, not too bright.
 - Avoid shiny papers.
 - Avoid continued severe use, producing fatigue.
 - Avoid reading in failing evening light.
 - Serious troubles follow abuse of eyes.
6. Hygiene of bathing.
 - Hot baths for decency and cleanliness
 - not to "open the pores"
 - not too frequently
 - best at bed time to avoid chilling
 - Cold baths to train body against chilling
 - should be followed by rubbing and "glow"
 - best taken in morning
 - not too cold nor too prolonged.
7. Care of the teeth.
 - Conditions in mouth favor bacterial growth.
 - Harm to teeth from bacteria, decay and loss.
 - Other damage to health and looks, due to poor teeth.
8. Hygiene of the feet.
 - Danger from improper shoes.
 - Shape and material of shoes.
 - Correct habits of walking.
 - Support of the arches of the feet.
9. Correct posture.
 - Standing position.
 - Sitting position.
10. Hygiene of the nervous system.
 - Great development of nervous system.
 - Possibility of over strain and neglect of rest of body.
 - Importance of well-trained brain.
 - Importance of sleep.

CHAPTER XLV

CIVIC BIOLOGY

Vocabulary

Pessimism, looking on the "dark side" of things.

Civic, pertaining to government.

Prolific, abundant.

Conservation, saving from waste or damage.

Addiction, the grip of habit.

The preceding chapter has dealt mainly with biology as related to the individual, but more important is our duty to the health of the community, state, and nation.

Out of two and one-half million babies born in the United States every year, one half die before reaching the age of twenty-three years, and 500,000 die before their first birthday. Of the adults, 40,000 will have been invalids, 5000 will be in various institutions for mentally or physically unfit, and 100,000 will be inferior to the extent of reducing their value as citizens.

School examinations in Brooklyn show that 72 per cent of the pupils need some form of medical treatment. If this ratio holds for the United States it would mean 14,000,000 children who are in need of health improvement. These figures are not given to cause any feeling of pessimism or discouragement, but rather to show what great need there is for civic control in all matters pertaining to health, and for the intelligent coöperation of every citizen in these measures.

Already modern methods of hygiene and sanitation have added fifteen years to the human life. In the Spanish war we lost fourteen men by disease for every one that died of wounds. In the Russo-Japanese war, with modern sanitary precautions in force, the Japanese lost only one by disease for every four killed, a record fifty-six times as good as ours.

No complete figures are available for the World War, but it is certain that never before have the modern principles of sanitation, vaccination, serum treatment, surgery, and the relation of insects to disease, been so thoroughly applied.

Vaccination against typhoid was compulsory, the anti-tetanus serum was universally used, new methods of treatment for infected wounds, devised by Dr. Carrell and others, were in constant use. Every soldier was provided with iodine to sterilize a wound and aseptic bandages to make a temporary dressing.

As a result of these various applications of biologic science to army methods, the loss from infectious disease was very low. "If the Civil War death rate had obtained in the recent war, we would have lost 138,518 American soldiers from typhoid, dysentery, malaria, and small-pox instead of 273, which was the actual number," says Dr. Henry Smith Williams in one report (Dec. 1919).

We are waging a winning fight against disease and this chapter will touch briefly upon some of the methods by which it is being carried on. We are all soldiers in the army of Public Health and cannot be too well informed as to what must be done to gain complete victory.

Food Control. Almost every town and city has regulations as regards food inspection. The stores, bakeries, slaughter houses and milk stations are under supervision of official inspectors. Foods must be protected from flies, bread must be wrapped, food animals examined as to their health, and fair weight and measure must be given the purchaser.

Water supplies are provided at enormous expense, the water shed is carefully guarded from pollution, the water itself is filtered and chemically treated to remove bacteria. Chemists and bacteriologists are constantly employed to attend to these matters.

Milk has always been a prolific source of disease among young children and every means is now taken to secure its purity and freshness. The farmer must have healthy cows and healthy men to care for them, he must have clean stables and sterilized cans and utensils. The inspectors of state or city enforce a list of rules

covering in some cases over sixty items that tend toward supplying clean milk to the dealer in the city.

The dealer is again subject to equally careful control. He must not let the milk get warmer than fifty degrees, he must provide clean cans and handling conditions, he must sell in sealed and labeled bottles, and his milk must be subject to examination for bacteria, at any time. If any of these conditions are found dangerous, the milk is destroyed.

Milk normally contains bacteria, mostly harmless and some useful, but the total must not exceed 100,000 per cubic centimeter which is not very numerous for bacteria, though well-handled milk ought to be kept far below this limit. Milk must have at least 3.25 per cent of butter fat and must not contain any preservatives, such as borax, soda, or formaldehyde.

Sanitation. Regulations as to sewage and garbage disposal are in force in most cities, and means are provided at public expense for the sanitary disposal of all wastes. Stables and outhouses are either forbidden or restricted. Factories are not permitted to pollute the air or water with their waste products.

Streets are drained, sprinkled, oiled, paved, and flushed with water to remove dirt and to prevent dust. Trees and parks are provided to improve the air and give places for outdoor rest to the population.

Disease Prevention. It is in this department that modern hygiene has made its greatest progress. We now provide free hospitals, clinics, and dispensaries where the sick may receive treatment. We have visiting nurses, city physicians, and school health examinations to make sure that all who need help, shall receive it. Stringent laws regulate vaccination, quarantine, and disinfection of infected premises. Coughing, sneezing, and spitting are forbidden where they endanger the public health, and the public towel and drinking cup are, fortunately, things of the past.

Campaigns of education by printed matter, pictures, school instruction and lectures, have been undertaken by city, state, and national governments, as well as by life insurance companies and institutions like the Rockefeller Foundation.

As a result, we are becoming a longer lived and healthier nation. Dirt, vermin, and disease are recognized as alien enemies and are being removed or controlled.

Factory and Housing Conditions. The strongest constitution cannot endure dark, ill-ventilated or crowded homes and factories. Laws, inspection, and information are being combined to bring about better conditions.

In most states child labor is forbidden or restricted, housing conditions are looked after to some extent and fire protection is usually well provided.

To carry out these many lines of civic biology, cities and towns usually have a Board of Health, inspectors, and the assistance of the police. In large cities public laboratories are maintained where examinations of food, milk, water, and disease cultures are made. There may be one or more city physicians, city chemists, and visiting nurses who help enforce and carry out the regulations.

The street cleaning and fire departments perform their obvious part as well as the city engineers who look after the drains, sewers, and parks.

The Federal government devotes much of the work of the Department of Agriculture and the Department of Commerce and Labor, to matters pertaining to national health and the conservation of natural resources. They distribute quantities of valuable literature, and carry out investigations along varied lines of civic biology.

The Federal "Pure Food and Drugs" law was enacted in 1906 and regulates

1. Inspection of all food animals.
2. Standards of purity for food products.
3. Freedom from adulteration.
4. Prevention of harmful preservatives.
5. Proper labeling of drugs and medicines.
6. Proper labeling of package goods.

Patent Medicines. The consumption of patent medicines costs the people of the United States \$200,000,000 per year. This would

be well enough if the people were benefited by their use, but this is rarely the case. On the other hand, most of them are fakes, some are positively dangerous, all are outrageously expensive, and in many cases their use delays proper treatment, till too late.

The Food and Drugs law obliged them to make no claims to "cure" unless they could prove their claims and this rule has practically removed that word from their vocabulary of fiction.

No patent medicine ever *cured* consumption, nor "kidney trouble," nor catarrh, and they now are more careful in the wording of their advertisements, though they still try to convey the same impression.

"Consumption cures" are mainly opiates which lull the sufferer into false security until past all help. Tonics and sarsaparillas depend wholly upon alcohol for their effect. "Soothing Syrups" for helpless babies are opium and morphine mixtures and frequently lay the foundation for drug habits in later life, if indeed the baby is not "soothed" into the sleep that knows no waking.

Headache remedies are all heart-depressing drugs which deaden the pain but do not remove the cause, of which the pain was merely a warning.

Catarrh cures are usually cocaine or opium mixtures and often lead to drug addiction; under recent laws they are much restricted.

The Food and Drug Law does not forbid the sale of these medicines but it does oblige the maker to do two things:

1. He must put on the label the amounts of alcohol, morphine, cocaine, opium, or other harmful drug which his medicine contains.
2. He must not "make any false or misleading statement" as to the virtues of his particular "remedy."

This is one of the chief values of the law and applies to food stuffs as well as medicines, so the only way to obtain the protection which the law affords, is by reading the labels before you buy.

One can often judge of the character of a newspaper or magazine, from the number and kind of patent medicine advertisements which it carries. A reputable periodical will not now open its columns to the false and misleading claims which some medicine

manufacturers offer. Look over the literature that comes to your home and draw your own conclusions.

COLLATERAL READING

Principles of Health Control, Walters, pp. 373-396; *Civics and Health*, Allen, entire; *The Human Mechanism*, Hough and Sedgwick, pp. 477-540; *A Handbook of Health*, Hutchinson, entire; *Community Hygiene*, Hutchinson, entire; *Civic Biology*, Hunter, pp. 373-396; *Town and City*, Jewett, entire; *Sanitation Practically Applied*, Wood, see index; *Handbook of Sanitation*, Price, see index; *Sanitation in Daily Life*, Richards, look through.

Bulletins of U. S. Department of Agriculture, *State Departments of Health*, *Rockefeller Foundation*, *City Health Departments*.

SUMMARY

1. Our responsibility for welfare of others.
2. The needs, as shown by health conditions.
3. Results of modern methods of hygiene.
4. Food control.
Food. Water. Milk.
5. Sanitation.
Sewage and garbage disposal.
Building restrictions.
Care of streets, parks, and trees.
6. Disease prevention.
Free care for the sick.
School examinations and clinics.
Laws as to spitting, etc.
Education in hygiene and cleanliness.
National, state, and individual publications and help.
7. Factory and housing conditions.
Laws as to conditions and hours of work.
Laws as to child labor. Compulsory school attendance.
Various boards and inspectors to carry out work in Civic Biology.
8. The Pure Food and Drugs Law.
9. Patent medicines.

CHAPTER XLVI

THE ECONOMIC BIOLOGY OF PLANTS

Vocabulary

Economic, pertaining to man's use.

Solvent, a substance used to dissolve others.

Utilize, to use.

Economic biology deals with the relation of living things to man, either for use or for harm. The "economic importance" of a plant or animal does not mean merely its *value* to man, but also includes any way in which it may damage him. Usually the uses outnumber the injuries, but do not forget that both are included.

General Uses of Plants.

1. To supply oxygen and remove carbon dioxide in photosynthesis.
2. To aid in returning nitrogen compounds to the soil.
3. To regulate drainage of water (forests).
4. To supply foods for man and animals.
5. To provide fabric fibers (cotton, linen, hemp).
6. To provide fuel (wood, peat, and coal).
7. To provide paper materials.
8. To provide timber, cork, rubber.
9. To provide tanning materials (hemlock, oak and other barks).
10. To provide dye stuffs.
11. To provide drugs and medicine, alcohol.
12. To provide turpentine, wood alcohol, acetic acid.

To balance this long list of uses for plant products, there are but few ways in which they ever harm mankind. Some of these have been studied in Chapter 17.

Of course *bacteria* head the list of harmful plants, in that they cause many diseases, but do not forget that most bacteria are

useful and that some disease germs are not bacteria at all, but are protozoan animals. Other fungi also cause harm to man's crops and foods: among these are the rusts, molds, smuts, and mildews, which have also been studied before. Some plants are *poisonous* and do a little harm in that way, among these may be mentioned certain mushrooms, poison ivy, water hemlock, etc. In cultivated land, many wild plants cause harm by interfering with crop growth. We call these "*weeds*" and they demand much labor and expense for their control.

We shall now take up some of the economic applications of plant biology in detail.

Oxygen Supply. The importance of plants as a source of oxygen and in removal of carbon dioxide has been explained in Chapter 13 but cannot be over-emphasized. Without this action of plants, the supply of oxygen would be exhausted and no animal life could exist.

Nitrogen Fixation. The return of nitrogen compounds to the soil by the action of certain bacteria has also been mentioned (Chapter 17) and is one of the ways in which its fertility is maintained, while the natural decay of the plant tissue also aids in this same process.

Control of Drainage. The regulation of drainage is brought about by the forests, which act like enormous sponges, soaking up the rains and letting the water filter slowly through the soil, instead of rushing off in floods, as it does when heavy rains fall on barren regions.

Foods. Cereal Grains. Of all plant parts used for food by man, seeds are the most important, and among them the cereal grains easily take first place.

These cereals (whence the name?) are the fruits of various grasses and include wheat, corn, rice, rye, barley, oats, etc. They constitute the most important group of food stuffs used by man or other animals. In their composition these grains contain but little water, hence they keep well, and store considerable food in a small bulk: they are all rich in starch. Wheat contains much proteid (gluten) and corn is well supplied with oil, of which the other grains contain but little.

The proteid of wheat makes its flour produce a sticky batter resulting in the spongy "light" loaf which no other grain will yield. Macaroni is another wheat product that depends on this



FIG. 137 Wheat, (*Triticum sativum*, Grass Family, *Gramineae*). A plant and flower-cluster of beardless or "club" wheat, a piece of the zigzag rachis, a spikelet, a flower, and a kernel. (Baillon.) From Sargent.

fact for its wide use. The lack of fat in most cereals is made up for by using butter, milk, or cheese with them when possible.

All cereals, especially if the whole grain be used, supply phos-

phorus, sulphur, potassium, calcium, magnesium, and sodium compounds which are so essential to proper rations. (See Chapter 37.) They are easily cultivated, ripen quickly, yield largely, and so constitute one of the first and most important crops raised by man. The history of the cereals is the history of the human race, wheat being found imbedded in Egyptian brick five thousand years old. Other grains are found among the relics of the Swiss Lake dwellers, perhaps much older, while the Chinese have cultivated rice for over four thousand years and corn was used in America long before the dawn of history.

Kinds of Cereals. *Wheat* is the most important vegetable food in Europe and America. The United States leads in its production with Russia in second place. Not only does it provide the white bread of the world, but macaroni, spaghetti, vermicelli, etc., are also wheat products.

Rice feeds more people than any other grain, being the chief cereal of China, India, and southern United States and it is estimated that one-half the population of the world depends upon it.

Corn was one of the first cereals to be used by savage tribes because it is easily cultivated in almost any climate; United States also leads in the production of this grain. Not only is it valuable as food for men and animals, as meal, canned or fresh, but starch, corn syrup, glucose, oil, and gluten foods are among its products.

Oats will thrive in colder climates than any other grain. It is the principal cereal of Scotland, Norway, Sweden, and Iceland, and is used for food and fodder in other temperate regions.

Barley also endures cold but will thrive in warmer regions as well; it was formerly a valuable food, but is now more used for fodder and for malt to make beer.

Rye will grow in poorer and rougher soil than any other grain and Russia leads the world in its production. It makes the common "black bread" of Austria, Germany, Russia, and Sweden.

Buckwheat, despite its name, is not a true grain and while pleasant in flavor, its flour has little food value; it is a native of northern Asia and will grow in poor soil in temperate climates.



FIG. 138. Rice (*Oryza sativa*, Grass Family, *Gramineæ*). *P*, upper part of rice plant, one-quarter natural size; *S*, a spikelet from the same; *w*, rain-guard or ligule at base of leaf-blade, inner view; natural size. (Martius.) From Sargent.

Legumes. Next in importance to the cereals among the seeds used for food are the *legumes* (peas, beans, and lentils) all



FIG. 139. Peanut (*Arachis hypogæa*, Pulse Family, *Leguminosæ*).

A, lower part of a plant showing the leaves and flowers above ground, and ripening nuts and roots below; the surface of the ground indicated at *cl.* *B*, a flower cut vertically to show, at the base, the small ovary containing the ovules, and the long style extending through a slender tube which is surmounted by the calyx and corolla and is continued by a tube formed of the united filaments. *C*, a ripe nut cut lengthwise to show the two seeds. (Tanbert.)—The plant is an *annual*, i.e., it completes its life from seed to seed in one year; stems and leaves somewhat hairy; flowers orange-yellow, fruit pale. Soon after pollen has come upon the stigma, the stamens and corolla are shed and the ovary is carried out beyond the calyx by a stalk which becomes 5–8 cm. long, and, bending downwards, soon buries the little ovary in the ground. Once buried the ovary ripens into the familiar pod-like nut. If it fails to get buried the ovary withers. From Sargent.

members of the pea family to which also belong the clover, locust, etc.

The legumes are very valuable foods, rich in proteid and starch, have little water or oil and hence keep well, though their proteid (legumin) is not so easily digested as animal forms.



FIG. 140. Coconut Palm (*Cocos nucifera*, Palm Family, *Palmaeae*). Plants in fruit showing general form. (Baillon.) The columnar trunk rises to a height of 20-30 m. and bears bright green leaves 6-7 m. long.

high. Coffee belongs to the same family as quinine and madder (a dye plant) as well as our common bluetts, partridge berry, and bed straw, and grows only in tropical regions, mainly in Brazil, Arabia, and the East Indies.

Cocoa is more valuable as a food than coffee, though less used

Nuts. Nuts are larger and richer in proteid and oil than grains or legumes but are less used for food, because the crop takes too long to mature and is too bulky to store. Nuts also contain so much oil that they do not keep nor digest well.

The chestnut has little oil and more starch than other varieties. It is used for food in Europe as are also walnuts and pecans, to some extent, while the people of the tropics use coconuts, peanuts, and Brazil-nuts because cereals do not thrive in such climates.

Other Seed Foods. Coffee is a very valuable seed food product. It is the seed of a fleshy berry borne on a shrub about 15 feet

It is the seed of a small tropical tree growing in South and Central America, Africa, and Ceylon. From the "cocoa bean," as it is called, are made cocoa, chocolate, and cocoa butter. It must be



FIG. 141. Coconut.

A, fruit, showing husk cut vertically through the center, revealing the hard shell of the nut.

B, nut viewed from below, showing the lines (*a, a, a*) along which the three pistils are united; and between them the three germ pores, from the lower one of which, ordinarily, the single germ emerges in sprouting.

C, lengthwise section through the fruit sprouting; notice the thick husk, into and through which the young roots grow, the hard shell of the nut (black) within which is the layer of solid seed food (coarsely dotted), and the liquid food or "milk" (white) into which the enlarging cotyledon or seed leaf (finely dotted) pushes its way and acts as an organ of absorption. (Warming.) The husk is smooth and grayish brown, and is largely composed of coarse, tough fibers. From Sargent.

observed that cocoa has nothing whatever to do with the coconut which is a palm fruit while still another plant (coca) furnishes from its leaves the dangerous drug cocaine.

Notice the different spellings: COCOA, beverage, chocolate; COCONUT, food product, palm; COCA, plant, cocaine.

Another valuable group of seed products includes many *spices*, such as mustard, nutmeg, mace, anise, celery, and caraway, while castor oil and strychnine are important medicines obtained from seeds.

Many seeds produce useful *oils* among which should be mentioned cotton-seed, peanut, and almond, which are used for food; cocoa and corn oils for soap and linseed (flax) oil for paints.

In all these important foods that man obtains from seeds, he has been using the store of nourishment intended for use by the embryo plant. Most seeds "keep" well and have a very concentrated store of food, an adaptation for reproduction of the plant, which man has utilized for his own benefit.

Root Food Materials. *Roots* furnish a large part of one of man's most valuable foods, namely, sugar. Sugar beets now produce over half the world's supply of "granulated" or "white" sugar; the rest comes from the stem of the sugar cane. Other products from the beet-sugar industry are potash for glass-making, fodder for cattle, and waste for fertilizer.

Among our common garden vegetables we have the roots of beet, turnip, carrot, radish, parsnip, and sweet potato (not the common potato, which is an underground stem).

Ginger, licorice, rhubarb, marshmallow, tapioca, and aconite are all root products, used for food or medicines.

Stem Food Materials. *Stems* provide many forms of food among which the sugar cane takes the lead and the potato comes next in order.

Potatoes are used directly as food, and also furnish starch and dextrine, the latter being the gum used on stamps, labels, etc., and also for finishing many kinds of cloth.

The pith of a certain palm stem furnishes sago starch and pear tapioca while arrow-root starch is from the underground stem of a West Indian plant and is the most easily digested of all starches. Cinnamon bark, asparagus, camphor, and witch hazel are food and drug products also derived from stems.

Leaf Food Products. We usually think of leaves as fodder for animals (grass, hay, etc.), but notice the list of those that we commonly use ourselves. We must include the garden vegetables, cabbage, lettuce, celery, spinach, pie plant, parsley, onion, cress; the flavors of mint and wintergreen; tea and tobacco; and the drugs, cocaine and belladonna. Although leaves have little real nourishment in them because not intended as storage places for food, yet they are necessary to man's diet, since they supply many of the mineral salts, especially iron and potassium compounds, which are essential to health.

Flowers. *Flowers* we seldom eat, but cauliflower is one exception, and cloves and capers are both flower products.

Fruits. *Fruits* furnish an extended list of foods for man. We classify them as follows: pomes, such as apples, pears, and quinces; stone fruits, like the peach, plum, cherry, apricot, and prunes; citrus fruits, orange, lemon, grape fruit; simple berries, currant, grape (raisin), blueberry, tomato; compound berries, such as raspberry, strawberry, and blackberry; gourd fruits, pumpkin, squash, cucumber, melon, and citron; miscellaneous, banana, date, olive, peppers, vanilla, allspice.

Hops and opium are also fruit products and, though not foods, may be mentioned at this point. Like leaves, fruits are not often very concentrated foods, but supply sugar, acids, and mineral salts which are very necessary to a proper diet.

Foods from the Spore Plants. The spore plants furnish but little toward man's food, mushrooms being the only ones commonly eaten, and of these many are dangerous and the best only one-sixth as rich in proteid as meat.

Iceland moss is a curious lichen sometimes used in jellies and medicines. Though we do not eat them to any extent we must not forget that we could not do without spore plants, such as yeast and certain bacteria that help in preparing such important foods as bread, butter, and cheese.

Fiber Plants. *Cotton* is the most valuable plant fiber; it is an outgrowth of the outer coat of the cotton-seed, intended to aid in its dispersal, and consists of strong, twisted fibers very well adapted



FIG. 142. Sugar-cane (*Saccharum officinarum*, Grass Family, *Gramineæ*). Plant in flower. *A*, part of spike, showing long silky hairs. *B*, spikelet detached. *C*, flower, showing stamens, pistil and lodicules at the base. (Bentley and Trimen.) — Perennial, attaining a height of 13 ft.; stem variously colored, 2–5 cm. thick. From Sargent.

for spinning. Not only is cotton made into thread and cloth, but into batting, surgical dressings, paper, celluloid, and gun cotton.

Flax which is the bast fiber of the bark of the plant of that name, ranks next to cotton in value. From it are made linen thread, cloth, and lace; canvas, duck, carpet warp, oil cloth, fine paper,



FIG. 143. Iceland Moss (*Cetraria islandica*, Shield-lichen Family, *Parmeliaceæ*). Plant, natural size, growing nearly erect from dry earth. (Luerssen.) — Upper surface brownish or olive, pale below, often red-stained at the base; "fruit" forming chestnut-colored patches on the uppermost lobes. Native home, North America and Eurasia. From Sargent.

and parchment. It is harder to prepare than cotton and is grown chiefly in North Europe.

Jute is the bast fiber of certain plants of India; it is not so fine nor durable as linen but is made into burlap, sacking, webbing, and cordage.

Hemp is the bast fiber of a member of the nettle family and is cultivated largely in Europe for its fiber uses, while in Asia an intoxicating drug is prepared from the same plant. Hemp is coarse, but stronger than flax and is used for sail cloth, cordage, and oakum.

Manila fiber is obtained from the leaves (veins) of a banana-

like plant of the Philippines. From this are made the best ropes, binder twine, bagging, and sail cloth.

Coconut fiber comes from the outer husk of the coconut and is used for cordage and for the familiar brown door mats.



FIG. 144. Sea Island Cotton (*Gossypium barbadense*, Mallow Family, *Malvaceæ*). Flowering top, $\frac{1}{4}$. (Schumann.) — Similar to upland cotton but with seed black. Native home, West Indies. From Sargent.

Other uses for vegetable fibers are in the manufacture of cheap brushes, brooms, matting, packing, and upholstery.

Fuels. The next topic in our list of plant uses is fuel. While this is of enormous importance, it needs little explanation, as all are familiar with coal and wood and must know that gas is made from the former. *Peat* is an important fuel in some parts of Europe.

and consists of the partly decomposed and compressed peat moss, similar to that in which florists pack their plants. From coal are



FIG. 145. Flax (*Linum usitatissimum*, Flax Family, *Linaceæ*). Plant in flower. Young flower-cluster. Seed, entire and cut vertically. (Baillon.) Annual, about 60 cm. tall; leaves smooth; flowers light blue; fruit dry. Native home, Southeastern Europe and Asia Minor. From Sargent.

also obtained a vast number of dyes, medicines, explosives, and other products which will be studied in chemistry.

Paper Materials. All forms of paper are made from plant material, chiefly from wood fibers of spruce, poplar, and similar trees.

Cotton waste, linen, and jute are important paper materials while in Japan the young stems of the paper mulberry are used.

Timber. The matter of timber structure and of forest products in general will be taken up later. The uses of timber are so numerous that only a few can be mentioned; among these are:

General building
Ships
Vehicles
Pavements
Railroad ties

Furniture
Boxes
Bridges
Poles
Mine timbers



FIG. 146. Harvesting cork. (Figuier.) From Sargent.

Willow, ash, and hickory are split for making baskets, chairs, and hats; rattan and wicker work are from similar sources. Pine and spruce furnish excelsior for packing. Cedar supplies our pencils, and mahogany and other fine woods are cut into veneers.

Two other very valuable tree products, though not timbers, are cork and rubber. Cork is obtained from the bark of the cork oak which grows largely in Southern Europe and is used not only for stoppers, but to make linoleum, life preservers, packing, artificial limbs, handles, etc.

Rubber is made from the milky juice of several tropical trees of South America and Asia; its uses are many and varied and familiar to most of us.

Tanning Materials. The principal tanning materials are obtained from the bark of the oak, hemlock, willow, birch (Russia leather), chestnut, and the South American quebracho.

Dyestuffs. Vegetable dyes have become much less important since the development of the coal tar or aniline colors, however indigo, logwood, and gamboge may be mentioned. The indigo plant grows in India and Java and furnishes the familiar blue dye; logwood grows in Central and South America and furnishes red and black dyes, while gamboge is a yellow dye grown in Siam.

Drugs. Several drug products have been mentioned elsewhere so that merely a brief list will be given here:

Gums: Camphor (China), Arabic (Africa), Tragacanth (Asia).

Witch hazel from leaves and stems of a native plant.

Opium from milk of Chinese and Indian poppy fruits.

Cocaine from coca leaves (Peru).

Quinine from chinchona bark (Peru).

Strychnine, atropine, and nicotine are important plant drugs.

Alcohol is one of the most important plant drug products; it has a multitude of uses other than as a beverage. It is utilized in all chemical industries, as a solvent, fuel, preservative, and in many other useful ways.

Alcohol is made by the action of yeast ferments on several kinds of sugars. Apples, rye, and corn furnish whiskey; barley malt is used for beer; grapes provide the sugar solution for wines; molasses ferments to make rum.

All of these and some waste sugar liquors are fermented and distilled to make commercial alcohol.

Distillation Products. The last topic in our list of plant uses includes several products from distillation of wood or pitch. Crude turpentine is the pitch of certain kinds of pine found in our Southern States, France, and Russia. From it the common turpentine is made by distillation and rosin is left as a residue. Turpentine

is used in paints, and rosin in all kinds of varnish, soaps, cements, and soldering. Wood alcohol, acetic acid, and charcoal are all



FIG. 147. Dyer's Indigo Shrub (*Indigofera tinctoria*, Pulse Family, *Leguminosæ*). Flowering branch; *a*, flower, enlarged; *b*, standard (uppermost petal), back view; *c*, wing (side petal), inner view; *d*, *e*, keel-petal, inner and outer views; *f*, flower with corolla removed; *g*, pistil; *h*, fruit, natural size; *i*, seed; *k*, same, cut vertically. (Berg and Schmidt.) — Shrub growing 2 m. tall; leaves downy beneath; flowers reddish yellow; fruit dry. Native home, Southern Asia. From Sargent.

made by distilling any kind of wood in large closed vessels. It is an important industry in many wooded regions.

COLLATERAL READING

Elementary Studies in Botany, Coulter, pp. 342-418; *Botany for Schools*, Atkinson, pp. 392-420; *The World's Commercial Products*, Freeman and Chandler, entire; *Plants and their Uses*, Sargent, entire; *Elementary Biology*, Peabody and Hunt, pp. 126-153; *Domesticated Plants and Animals*, Davenport, entire.

SUMMARY

Economic biology, the relation of living things to man, whether for good or harm.

General uses of plants.

- | | |
|--|----------------------------|
| 1. Supply oxygen, remove CO ₂ . | 7. Paper materials. |
| 2. Regulate drainage. | 8. Timber, cork, rubber. |
| 3. Return nitrogen to soil. | 9. Tanning materials. |
| 4. Foods for men and animals. | 10. Fabric fibers. |
| 5. Fuel. | 11. Dyestuffs. |
| 6. Drugs, medicines, alcohol. | 12. Distillation products. |

Harmful plant forms.

1. Some bacteria (disease).
2. Some fungi (destroy crops, timber, etc.).
3. Poisonous plants.
4. Weeds.

Plant uses in detail.

1. Oxygen supply (Chap. 13), photosynthesis.
2. Nitrogen fixation (Chap. 17), soil bacteria, decay.
3. Drainage control (Chap. 50), forests as reservoirs.
4. Food materials.

Seed products.

<i>Plant</i>	<i>Location</i>	<i>Uses</i>
1. Cereals.		
Wheat	U. S., Russia	Bread, macaroni, etc. Principal food of white races.
Rice	China, India	Feeds half the world.
Corn	North America	Food, fodder, starch, oil, alcohol.
Oats	North Europe	Food, fodder.
Barley	Central Europe	Fodder, beer, food.
Rye	Europe	Dark bread, whiskey.

2. Legumes.

Beans	Generally cultivated	Important as proteid foods.
Peas		
Lentils.		

3. Nuts.

Chestnut	South Europe	Food, starch, little oil.
Coconut	Tropics	Food, fiber.
Peanuts	America	Food, oil, butter.

4. Various seeds.

Coffee	Asia, S. America	Beverage.
Cocoa	S. and Cent. Am.	Beverage, chocolate, butter.
Mustard	Various	Spices and flavors.
Nutmeg, etc.		
Cotton-seed	Various	Oils for food, soap, paint.
Peanut		
Almond		
Flax, cocoa		

Root products.

<i>Plant</i>	<i>Location</i>	<i>Uses</i>
Sugar beet	Europe, U. S.	Sugar, potash, fertilizer.
"Vegetables"		
Beet, carrot	Various	Food, supplying starch and minerals
turnip, parsnip		
Sweet potato	Southern U. S.	Food.
Ginger	India	Spice.
Licorice	Mediterranean countries	Flavor, medicine.
Rhubarb	Various	Medicine.
Aconite	Europe	Medicine.
Cassava (tapioca)	Africa	Food starch.

Stem products.

<i>Plant</i>	<i>Location</i>	<i>Uses</i>
Sugar cane	U. S., India, West Indies	Food, sugar, molasses, alcohol.
Potato	U. S., Europe	Food, starch, dextrine.
Sago palm	East Indies	Starch.
Arrow root	West Indies	Starch.
Asparagus	Various	Food.
Cinnamon	Ceylon	Spice from bark.
Camphor	China	Gum for medicine, celluloid, etc.

Leaf products.

<i>Plant</i>	<i>Location</i>	<i>Uses</i>
Onion, cabbage	Various	Food (mineral salts).
Lettuce, rhubarb	"	"
Mint, winter-green	Various	Flavors.
Tea	India, China	Beverage.
Tobacco	Various	Smoking and chewing.
Coca	S. America	Drug (cocaine).

Fruits.

Pomes, apple, pear	Stone fruits, plum, cherry, peach.
Citrous fruits, orange, lemon	Berries, grape, currant, tomato
Comp. berries, strawberry, etc.	Gourd fruits, squash, pumpkin, cucumber.
Various fruits, banana, date, olive, vanilla, hops, poppy (opium).	

Spore plant products.

Mushrooms	Yeast (in making bread).
Iceland moss (jelly)	Bacteria (in making butter, cheeses).

5. Fiber plants.

<i>Plant</i>	<i>Location</i>	<i>Uses.</i>
Cotton	India, Egypt, United States	Cloth, paper, explosives, batting, dressings, thread.
Flax	North Europe	Linen, canvas, paper, lace.
Jute	India	Burlap, sacking, cordage.
Hemp	Europe	Cordage, sail cloth, oakum.
Manila fiber	Philippines	Rope, twine, sail cloth.
Coconut fiber	Africa	Mats, brushes, upholstery.

6. Fuels.

Wood, charcoal, peat, coal, gas (by-products).

7. Paper.

Spruce, poplar, etc., cotton and linen waste.

8. Timber.

Buildings, furniture, ties, poles, boxes, baskets, chairs, pencils, excelsior, veneers.
 Cork, bark of cork oak, Southern Europe.
 Stoppers, life preservers, linoleum, etc.
 Rubber, juice of trees, South America and Asia
 Tires, stoppers, elastics, raincoats, etc.

9. Tanning materials.

Barks of oak, hemlock, willow, birch, chestnut, quebracho.

10. Dyestuffs.

Indigo, India, Java (blue).

Logwood, South and Central America (black or red).

Gamboge, Siam (yellow).

11. Drugs.

Gums, camphor, arabic, tragacanth.

Opium, China, India. Milk of poppy fruits.

Cocaine, Peru. Leaves of coca plant.

Quinine, Peru. Bark of chinchona plant.

Alcohol from apples, rye, corn — whiskey.

Alcohol from barley malt — beer.

Alcohol from grapes and fruits — wines.

Alcohol from molasses — rum.

12. Distillation products.

Charcoal, wood alcohol, acetic acid, turpentine, rosin, pitch, tar.

CHAPTER XLVII

THE ECONOMIC BIOLOGY OF INVERTEBRATES

Vocabulary

Polyp, the coral animal, which is *not* an "insect."

Succulent, juicy.

Bivalves, two-shelled animals, such as clams.

Venomous, poisonous.

We shall take up the economic relations of animals in the same way as we have plants, giving the general uses and harm done and then taking up each large animal group, somewhat in detail.

The subject is so broad that many books have been written on the economic relations of insects, birds, or mammals alone, so we will be required to consult reference books for fuller information.

Try especially to find as many examples of each case as possible, particularly animals which are familiar.

General Uses of Animals.

1. To supply food (flesh, eggs, milk, etc.).
2. For transportation (horse, ox, camel, dog).
3. To provide fabric fibers (silk, wool).
4. To provide fur (seal, mink, otter).
5. To provide leather (cattle, sheep, horse, etc.).
6. To provide feathers.
7. To provide various products, such as ivory, horn, glue, gelatine, hair, etc.
8. To aid in pollination and seed dispersal.
9. To act as scavengers.
10. To aid in destroying harmful animals and plants.

Harmful Kinds of Animals. From this list it is evident that man owes about as much to other animals as he does to plants. There are, however, a few harmful exceptions.

Certain protozoa cause disease (see Chap. 18 and 25) and some parasitic worms (Chap. 20) also do considerable harm. Many insects live upon the plants that man also uses for food and in this way cause serious destruction to crops, while others transmit disease (Chap. 25). To a very small extent "wild animals" harm man directly and also destroy some of his domestic animals, but this is of comparatively little importance.

Economic Value of Animals. In dealing with the economic im-

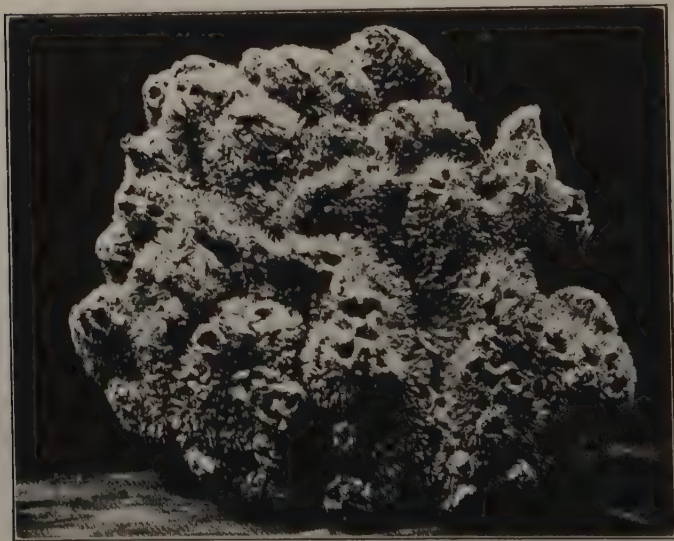


FIG. 148. A common bath sponge. From Kellogg and Doane.

portance of animals we shall take them up by groups beginning with the simplest first, namely the protozoa.

Protozoa. These minute one-celled forms are of vast importance to man insomuch as they are the source of food for higher animals and these in turn finally provide man with nourishment, by way of such important sources of food as clams, oysters, crustaceans, and fishes, many of which find, in protozoa, their chief food supply.

Certain protozoa develop minute shells and the deposits of these

tiny skeletons have produced great layers of chalk and other rock, which form important land areas such as the Dover cliffs in southern England. Some of the pyramids are made of stone formed from protozoan deposits.

Many protozoa perform valuable service as scavengers, and, since they are mostly aquatic, aid in keeping our water supply free from filth. On the other hand, a great many diseases are caused by protozoa, among which are malaria, smallpox, yellow fever, dysentery, scarlet fever, etc. (See Chap. 13.)

Sponges. From the next higher group, the sponges, man obtains the various forms of the common "sponge." The sponge is really the horny skeleton of the sponge animal, from which the jelly-like flesh has been removed by rotting and washing. Sponges grow attached to the sea bottom in various warm regions, such as the Mediterranean and Red Seas, and Florida and West-Indian waters. The best come from the Mediterranean. A live sponge is a roundish smooth mass, rather dark brown in color, provided with many pores for passage of water, and having about the consistency of a piece of beef liver.

They are collected by divers or by dragging hooks, piled on shore till the flesh rots off, washed, dried, sorted, and sometimes bleached. The world's annual sponge crop is worth about \$4,000,000.

Coelenterates. The coelenterates include many curious and beautiful animals such as the hydras, hydroids, jelly-fish, corals,



FIG. 149. Branching coral *Acropora muricata* from Samoa. (Much reduced.)
From Kellogg and Doane.

and sea-anemones, but the only forms directly of use to man are the corals. Colonies of these tiny animals, called coral polyps, secrete so much limestone in their body walls that they form the coral reefs which make up large parts of several continents, notably Australia and the Pacific islands. Other coral reefs of very ancient times now form important beds of limestone like the "corniferous" ledges that cross central New York. The red coral used for jewelry is another product of this group, found principally in the Mediterranean.

Echinoderms. The echinoderms include the starfish, sea-urchin, and sea-cucumber. Starfish are an enemy of the oyster and a special effort is made to keep them out of oyster beds. The Chinese and West Pacific peoples also use the sea-cucumbers for food, as soup, and consider them a great delicacy.

Worms. As already stated in our study of worms (Chapter 20), we owe to the humble earthworm a heavy debt for his services in



FIG. 150. Liver-fluke (*Fasciola hepatica*). (Nearly twice natural size.) From Kellogg and Doane.

keeping the soil in fertile condition; and we must not forget that without this work we should probably have much difficulty with our agriculture. On the other hand, the parasitic worms, such as tape-worm, hook-worm, trichina, and other

intestinal forms, cause serious disease or death in man. Similar forms, the flukes, infect our domestic animals, especially sheep, which they attack by way of the liver and cause the death of hundreds of thousands every year.

Molluscs. Primitive man, before he knew the use of fire, depended upon raw molluscs for much of his food, as the enormous shell heaps remaining to this day testify. Even yet we look upon oysters, clams, mussels, and scallops as useful foods or luxuries, depending on how far we live from the seacoasts where they are caught. In all, except the scallops, we eat the whole body, the bulk of which consists of the liver and reproductive glands. What

we hear called the "ears" are really the muscles that held the shell together and it is this muscle *only* which we eat in the case of the scallop.

Clams are found along our whole Atlantic coast; oysters are abundant south of Cape Cod with Chesapeake Bay as the center of the industry, having the largest production of any region in the world. The Pacific coast and foreign shores also furnish these succulent bivalves, but even so, Chesapeake oysters are in demand in the best markets of Europe, and the oyster yields the most valuable water crop in existence. It is the leading fishery product in fifteen different states. Aside from their value as food, mollusc shells furnish us with "mother of pearl" for buttons, handles, and ornaments, with crushed shell for chicken feeding, and with the precious pearl of the jewelry store.

These latter are found in "pearl oysters" (not the edible species) and are caused by the entrance within the shell of a grain of sand or the irritation of a parasitic worm, which makes the oyster secrete layer after layer of shell substance, to cover the offending particle, much as the hand protects itself from irritation by growing a callous layer. The most valuable pearls are found in the Persian Gulf and on the coasts of Ceylon. Fresh water clams furnish the irregular "baroque" pearls and are found largely in the Mississippi and its branches.

Shells have always been used for ornaments and formerly passed for money as well, the "cowrie" of Africa and the "wampum" of our Indians being two examples. Wampum consisted of beads cut from the colored parts of clam shells.

Snails and slugs are another group of molluscs, which, especially in France, are valued as food. They do considerable harm in gardens where they eat young seedlings and leaves. The shiny trails so often seen on sidewalks are left by the slugs in their travels.

A near relative is the abalone of the California coast, whose beautiful rainbow colored shell is used for ornaments and for a great deal of inlaying work.

The third group of molluscs is called the cephalopoda and includes the squid, cuttle fish, and octopus. Man uses squid for

fish bait, and obtains from the cuttle fish the true "sepia," a brown ink-like pigment which the animal squirts out to hide itself when attacked. The "cuttle bone" familiar in the canary cage is the internal shell of this same mollusc.

Crustacea. The larger crustaceans, lobsters, crabs, shrimps, and prawns are valuable sources of food to man; the smaller forms are equally valuable as food for fish, and all are useful scavengers. Of all these the lobster is most valuable. From twenty to thirty million are annually caught along the coasts of New England and Canada and the business is carefully regulated by



FIG. 151. The giant squid, *Ommatostrophes californica*. From specimen with body, exclusive of tentacles, four feet long, thrown by waves on the shore of the Bay of Monterey. From Kellogg.

law to prevent their destruction by over fishing. "Soft shell" crabs are merely the ordinary blue crabs, taken just after moulting and before their new shells have formed.

Barnacles are curious crustaceans which attach themselves to rocks, piles and even to the bodies of whales and bottoms of ships. In the latter place they interfere with easy sailing and have to be removed.

Acerata. Spiders as a whole are distinctly beneficial because of their destruction of flies and other insects; their bite is seldom serious to man, though some large tropical kinds can kill small birds. Scorpions are found in Southern United States and tropical

America and Africa; their abdomen ends in a venomous sting, which, while painful, is seldom fatal to man.

"Daddy-long-legs," which belongs to this group, is a very useful citizen because he feeds almost entirely on plant lice.

Mites and ticks are degenerate parasitic forms which live on the blood of mammals such as the dog, cattle, and man. The itch is a disease produced by a mite, but, thanks to the popularity of soap, it causes little trouble.

Insects. The economic relations of insects are so important and complicated that we can only summarize them here. Refer to any of the books on "economic zoölogy" to get a full idea of their importance. Over half of all insects are harmful, 250 species attack the apple, grape, and orange, alone.

As to their harmful activities, they

1. Destroy grain, vegetables, and fruit crops.

2. Convey many kinds of disease (flies and mosquitoes).

3. Injure domestic animals (flies and mosquitoes, etc.).

4. Destroy buildings, clothing, etc. (white ants and "moths").

5. Annoy and injure man by bites and stings.

Their total damage in United States is over \$200,000,000 per year.

On the other hand, we owe to the insects many useful processes and products such as

1. Pollenation of flowers of valuable plants.

2. Acting as scavengers (maggots, beetles).

3. Killing injurious insects (lady bugs which eat scale insects and ichneumon flies that destroy tree borers).

4. Furnish silk (silk moth cocoon).



FIG. 152. A scorpion, *Centrurus* sp., from California. (Natural size.) From Kellogg.

5. Furnish honey and wax (bees).
6. Furnish dye (cochineal red from a scale insect).
7. Furnish shellac (gum secreted by a scale insect).
8. Furnish ink material (gall insects).

The following are some of the common injurious insects, which you should know by sight, so as to destroy them whenever possible.

FRUIT TREE PESTS

Tent Caterpillar. Makes web nests in apple and cherry trees. Caterpillar dark, with white stripe; moths light brown with white stripe on front wings; eggs in belts around small twigs. Treatment: collect and burn egg masses; destroy nests; spray with poison early in the spring.

Codlin Moth. The familiar "apple worm" is the larva. Eggs laid in young apple just after petals form, the larva hatches in a few days and feeds around the core, making the "wormy" apple. Treatment: spray with poison just after petals have fallen and before the larva can get inside the fruit or calyx. This insect costs New York state \$3,000,000 per year.

Scale Insects. Small circular or oval scales on bark; these are the bodies of the females under which eggs are deposited. Each scale insect sucks its nourishment from the juices of the plant and by their large numbers do great damage. Treatment: spray with crude petroleum emulsion before buds start in spring; spray with kerosene or whale oil emulsion during summer.

SHADE TREE PESTS

Tussock Moth. Handsome caterpillars with three black tufts, four white tufts, and red head. Eggs covered by frothy white substance. Treatment: destroy egg masses and use poison sprays.

Cottony Maple Scale. Masses of cotton-like scales on twigs and leaves suck nourishment from tree like all scale insects. Treatment: spray with kerosene or whale oil soap emulsions.

Borers. Larvae of various beetles bore under the bark and into wood, loosening the bark, and killing trees; the irregular grooves

under old bark are caused by them. Treatment: destroy infested trees or branches; dig out borers in fall; encourage the birds.

GARDEN PESTS

Potato "Bug." A beetle whose familiar red larva does damage. Treatment: spray with poison. Arsenate of lead is better than the familiar Paris green.

Squash Bug. A *true* bug; bad odor; eggs under leaves; feeds by sucking juices. Treatment: kill adult bugs early in season to prevent egg laying; destroy eggs.

Cabbage Worm. Larva of white or yellow butterflies. Treatment: spray *young* plants with poison or dust older plants with lime; catch adults in nets.

HOUSEHOLD PESTS

Flies and Mosquitoes. (See Chapter 25.)

Buffalo Carpet Beetle. Adults one-eighth inch long; have white and red markings, may be brought in on flowers; larva covered with bristles; eat carpets, feathers, etc. Treatment: take up carpets and spray with benzine (outdoors); fill floor cracks; use rugs.

Cockroaches and Croton Bugs. True bugs; scavengers; very prolific. Treatment: use poisons, traps, cleanliness.

Clothes' Moths. Larva of small gray moth; often in webbed cases; attack fur, woolen, etc. Treatment: frequent brushing; tight packing; use of camphor or naphthalene; cold storage.

It will be noticed that some insects suck their food by piercing the bark, while others eat the foliage. The former have to be treated with "contact poisons," like oil emulsions and whale oil soap, which will kill if they touch the body. The latter are destroyed by "digestive poisons," such as Paris green and Hellebore, which the insects eat with their food.

Among the beneficial insects we should learn to recognize the "lady bug" a red beetle whose larvae feed on plant lice, and the lace wing fly whose larvae also favor the same diet and thus protect our plants. Another useful insect is the long-tailed *Thallessa*

with ovipositors two to four inches in length. This insect is often feared and destroyed when really it lives on wood borers and is very useful.

HARMFUL LEPIDOPTERA

Moths.

- Bee moth, eggs laid in hive at night.
- Meal moth, webs in meal, flour, and cereals.
- Leaf rollers.
- Codlin moth, eggs in apple blossoms; larvae are "apple-worms."
- Currant and cherry worms, leaf and web nests.
- Leaf miners, minute larvae eat parenchyma of leaves.
- Clothes' moths, case makers in woolens and furs.
- Peach tree borers, attack base of trees, dangerous.
- Canker worms, "measure worms."
- Currant worm, "measure worms."
- Army worm, attacks grains, dangerous.
- Tussock moth, eats shade and fruit tree leaves, dangerous.
- Gypsy moth, leaf eater, dangerous.
- Tent caterpillar, maker of "worms' nests," dangerous.

Butterflies.

- Larvae generally harmful in some degree as leaf eaters.
- Cabbage "worm," common and very harmful.

BENEFICIAL BEETLES

- Tiger beetles, predaceous, as adult and larva, on insects.
- Ground beetles, predaceous, very numerous, eat caterpillars and potato beetles.
- Water beetles, eat other larvae, snails, small fish, and decaying vegetation.
- Carion beetles, eat dead animals, manure, etc. Bury food.
- Rove beetles, eat decaying matter.
- Lady bug beetles, eat insect eggs, adults, lice, cottony scale.

HARMFUL BEETLES

- Dermestids, eat fur, wool, carpet, dried meats, museum specimens.
- Click beetles, larvae, wire worms, feed on grain roots.
- Wood borers, larvae in trees.
- Stag beetles, live on wood and sap.
- Scarabs, lamellicorn beetles, a large order,
 - Scavengers, dung beetles.
 - Leaf eaters, adult on leaves, larvae on roots.
 - Pollen eaters.
- Buck beetles, wood borers.
- Leaf beetles, potato "bug," asparagus and cucumber "bugs." Grape.
- Weevils, live on grains, nuts, fruits, etc., very harmful; engraver beetles under bark.

INSECTICIDES

- Chewing insects. May be poisoned in food.
 Larvae of lepidoptera and coleoptera.
 Currant worm and apple worm.
 Potato beetle and larvae.
 All other "worms," beetles, and "grubs."
 Sucking insects. Must be killed by contact poisons.
 Plant lice, aphids.
 Scale insects.
 True bugs (heteroptera).
 For chewing insects use digestive poisons, such as
 Paris green.
 Arsenate of lead.
 Hellebore.
 For sucking insects use contact poisons, such as
 Whale oil soap
 Kerosene emulsion } for lice.
 Lime-sulphur wash for scale insects.
 For apples use,
 2-3 lb. arsenate of lead, $1\frac{1}{2}$ gal. lime-sulphur, 50 gallons water.
 For peach, plum, cherry, etc., use,
 2 lb. arsenate of lead, $\frac{1}{2}$ gal. lime-sulphur, 50 gallons of water.
 For winter spraying use one part lime-sulphur to eight water.

FUNGICIDES

- Use for blight, mould, rust, rot, or scab the following:
 Bordeaux mixture.
 Dilute lime-sulphur wash, as follows:
 For apples, pears, etc.,
 $1\frac{1}{2}$ lime sulphur to 50 gallons water.
 For plum, cherry, peach,
 $\frac{1}{2}$ gallon lime-sulphur to 50 gallons of water.

COLLATERAL READING

Economic Zoölogy, Osborne, pp. 1-300; *Insects Injurious to Fruits*, Saunders, see index; *Insect Pests of Farm, Garden and Orchard*, Sanderson, see index; *Economic Entomology*, Smith, see index; *Shell Fish Industry*, Kellogg, see index; *Essentials of Biology*, Hunter, Coral, p. 210; *Worms*, pp. 215-219; *Insects*, pp. 261-265; *Lobster*, 228; *Molluscs*, pp. 269-271; *Elementary Biology*, Peabody and Hunt, Bees (A. B.), p. 42; *Insects* (A. B.), pp. 13-22; *Crustacea* (A. B.), p. 162; *Protozoa* (A. B.), p. 173; *Applied Biology*, Bigelow, *Protozoa*, pp. 312-316; *Worms*, pp. 340-345, 350; *Crustacea*, p. 372; *Insects*, pp. 390-398; *Vegetable Mould and Earthworms*, Darwin, Chap. VII; *New York State Museum Bulletin*, No. 103 and other N. Y. State Bulletins; Cornell University College of Agriculture, Bul-

letins Nos. 142, 234, 252, 283, 333 and others. Rural School Leaflets, list on application.

U. S. Department of Agriculture Bulletins, Farmers' Bulletins Nos. 165, 264, 275, 564, etc., Bulletin No. 492, etc., Circulars Nos. 36, 98, etc.

The above Government publications are merely a suggestion; lists can be had for the asking, and hundreds of useful pamphlets can be obtained, especially in regard to insects.

(See also Chapter 25 on "Insects and Disease.")

SUMMARY

General uses of animals.

- | | |
|--------------------|---------------------------------------|
| 1. Food. | 6. Feathers. |
| 2. Transportation. | 7. Ivory, horn, glue, hair, gelatine. |
| 3. Fabric fibers. | 8. Pollenation, seed dispersal. |
| 4. Fur. | 9. Scavengers. |
| 5. Leather. | 10. Destroying harmful forms. |

Harmful kinds of animals.

1. Protozoa (diseases).
2. Insects (destroy crops). (Transmit disease.)
3. Wild animals (destroy man and domestic animals).

Economic value of animals.

Protozoa.

1. Food for higher animals, clams, crustacea, fish, etc.
2. Deposit shell as chalk beds.
3. Act as scavengers in water.

Sponges.

1. Skeleton of horny forms used as "bath sponge."
2. Preparation: collected, rotted, washed, dried, bleached.

Coelenterates.

1. Corals, reef, and continent builders.
2. Coral deposits, now limestone beds.
3. Precious coral.

Echinoderms.

1. Starfish harmful to oysters.
2. Sea-cucumbers eaten by Chinese, etc.

Worms.

1. Earthworms necessary in cultivated soil.
2. Parasitic worms cause disease in man and animals.

Molluscs.

1. Raw food, also cooked, clams, oysters, etc.
2. Shells furnish mother-of-pearl, buttons, chicken feed.
3. Precious pearls (Persia and Ceylon).
4. Shells for money and ornament.
5. Squids for bait and cuttle bone, sepia.

Crustacea.

1. Lobster, crab, shrimp, etc., for food.
2. Small forms for fish food, barnacles harmful.

Acerata.

1. Spiders useful in killing flies, etc.
2. Scorpions dangerous, but not fatal.
3. Daddy-long-legs feeds on plant lice.
4. Mites and ticks, parasitic and harmful to man and animals.

Harmful activities.

Insects.

- | | |
|--------------------------|---------------------------------|
| 1. Destroy crops. | 3. Injure domestic animals. |
| 2. Transmit disease. | 4. Destroy clothing, buildings. |
| 5. Annoy and injure man. | |

Useful activities.

- | | |
|----------------------------|---------------------------|
| 1. Pollenation. | 5. Furnish honey and wax. |
| 2. Scavengers. | 6. Dyes. |
| 3. Kill injurious insects. | 7. Shellac. |
| 4. Silk. | 8. Ink material. |

Common Injurious Insects.

Fruit tree pests.

- Tent caterpillar.
- Codlin moth.
- Scale insects.

Shade tree pests.

- Tussock moth.
- Cottony maple scale.
- Various "borers."

Garden pests.

- Potato "bug."
- Squash bug.
- Cabbage "worm."

Household pests.

- Flies and mosquitoes.
- Buffalo carpet beetle.
- Cockroaches, croton bugs.
- Clothes' moths.

Treatment.

- Sucking insects with contact poisons.
- Eating insects with digestive poisons.

Useful forms.

- Lady bug.
- Thalessa (an ichneumon fly).
- Carriion beetles.

CHAPTER XLVIII

THE ECONOMIC BIOLOGY OF VERTEBRATES

Vocabulary

Isinglass, a kind of gelatin, *not* the substance in coal stove windows, which is mica.

Appropriate, to take away for use (used as a verb).

Appropriate, suitable (used as an adjective.)

Fishes. The chief value of fish is as food, both for other animals and for man. Out of 12,000 known species, at least 5000 are valuable as human food.

The annual catch of salmon, cod, halibut, mackerel, and herring, amounts to many millions of dollars, while the shad, smelt, perch, and bass are almost as valuable. The Pacific salmon alone are worth about \$15,000,000 per year and the Atlantic cod returns about \$20,000,000. In fact it was the cod returns in fisheries that induced the settlement of New England and pictures of this celebrated fish may yet be seen in the state-house of Massachusetts, on the bank notes of Nova Scotia and the postage stamps of Newfoundland. The fish crop of Alaska in 1915 amounted to three times the purchase cost of the whole territory.

Fish are eaten fresh, smoked, salted, dried, pickled, and canned. Despite these various ways of preparation we do not use them as extensively as we should.

The Government maintains departments of fisheries in thirty-two states which regulate the times and methods of catching, provides hatcheries for artificial raising of valuable kinds and distributes young fish to stock ponds and rivers, so that the supply may not become exhausted.

Another important use for fish is as fertilizer since they are

rich in phosphorous compounds which most plants need. The menhaden is much used for this purpose as well as for its oil. In 1913 over a billion of this species were taken, from which were made 6,500,000 gallons of oil and 90,000 tons of fertilizer. The total weight of the year's catch of this one kind was more than the weight of all the inhabitants of Greater New York.

Cod liver oil is the easiest oxidized fat food in the world and is valuable as a medicine. Isinglass, a fine quality of gelatine is obtained from the air bladders of certain fishes. Glue is another important product made from waste parts and bones of all sorts of fish.

Amphibia. The chief value of this group lies in its activities in destroying harmful insects. Frogs, toads, and salamanders, all unite in feeding upon them, the toad being especially useful in this respect. To a very much less extent, frog legs are used for food; frogs might much better be left to fight insects, rather than be used for this purpose.

Reptiles. We usually consider this group as useless or even harmful, but with the rare exceptions of the venomous snakes, the Gila monster, and a few man-eating crocodiles, this is not true. Most snakes destroy either insects or harmful rodents, though a few eat frogs, birds, or eggs.

The turtle family not only destroys insects, but the tortoise furnishes flesh and eggs as foods and tortoise shell for ornaments. Alligators and crocodiles are not particularly valuable and occasionally are dangerous. Their hides are sometimes made into leather.

Birds. The economic value of birds has already been mentioned; they are our chief ally in the fight against our insect enemies; they provide flesh and eggs for food; they supply feathers for bedding and ornament; while their bright colors and sweet songs have always made them cheerful companions and pets for man.

In order to preserve these valuable members of society we can

1. Learn to observe the laws made for their protection.

2. Help restrain their enemies, the plume hunters, game hogs, cats, red squirrels, black snakes, and certain birds such as Cooper's

hawk, sharp-shinned hawk, great horned owl, and English sparrow.

3. Help preserve the forests and city trees for their nesting.
4. Provide winter food for city birds.
5. Provide nesting boxes for some city' species.
6. Try to inform others along these lines.

Mammals. *Food.* This group includes the animals that we usually think of as of the most importance to man. The ungulates furnish his chief sources of animal food, since here belong cattle, sheep, and pigs, and many others. Man uses as flesh food practically all hoofed animals with four toes, and from cattle also obtains, milk, butter, and cheese. Besides these, rabbits, squirrels, bears, raccoons, opossums, seals, and even bats, monkeys, and whales are important foods for man. In fact all mammals except the cat and dog families are used as food by some group of people or other.

Clothing. Next to their value as food, the mammal's chief products are their body coverings, which man appropriates. Sheep, goats, camels, and llama all produce valuable wools.

The list of fur-bearing animals includes the otter, mink, ermine, marten, and their relatives, together with foxes, wolves, bears, tiger, leopard, and even the humble skunk, while the sea otter and seal are much more valuable. The seal herd, belonging to the United States is the most valuable Government possession in the world. Leather is obtained from the hides of cattle, sheep, horse, hog, goat, seal, walrus, buffalo, and many other mammals and is absolutely indispensable because it has no satisfactory artificial substitute.

Various Products. The whale, largest of mammals, provides several curious products; oil and a fine wax (spermaceti) are obtained from some kinds. The oil whale also produces "whale bone" which is made from a fibrous strainer device developed from the roof of the mouth. Ambergris is an abnormal secretion of the liver of sperm whales which is of enormous value as a *perfume*.

Horn and bone products of many mammals are used for making

ornaments, buttons, handles, etc. Ivory comes from the tusks (teeth) of the elephant and walrus.

Transportation. Of much greater importance than these last items, is the use of many mammals as beasts of burden. The horse is easily first, with oxen, camels, dogs, goats, llamas, reindeer, water buffaloes, and elephants used in different countries to a greater or less extent.

Pets. Mammals have been used by many as companions and pets; in this class the dog is first, the horse, cat, and occasionally other forms being admitted to this select society.

Among the mammals, also, are most of the "domestic" animals which man has learned to tame and breed for many of the uses just mentioned. Here again, the dog comes first, as it was probably derived from a domesticated wolf which primitive man tamed for his company, protection, and aid in the hunt. Probably cattle or sheep were next controlled by man, though the horse may have preceded them in learning to carry his master in battle or the chase. To this list man is still adding useful species either by breeding from present forms, or by taming new ones when their value is discovered.

The other side of the account is represented by a few harmful mammals, dangerous either to man himself, to his domestic animals, or to his crops. Among these are the large carnivora, such as the tiger, lion, wolf, etc., which attack man or his flocks. In this country carnivora destroy about \$15,000,000 worth of stock per year. The rodents, especially rats, mice, and squirrels do enormous harm by destroying grains and other food stuffs. In the case of the rat alone, the wastage amounts to about \$200,000,000 annually. Furthermore, rats and some squirrels are infested with fleas which transmit the plague to man, and thus are even more seriously harmful. As a whole it will be seen that the mammals are not only extremely useful, but absolutely essential to man; without them our present civilization and mode of life would be impossible.

COLLATERAL READING

The following books have many references in various places; see index. *Familiar Fish*, McCarthy; *American Food and Game Fishes*, Jordan and Everman; *American Animals*, Stone and Cram; *American Natural History*, Hornaday; *Our Vanishing Wild Life*, Hornaday; *N. Y. Forest, Fish and Game Commission Reports*; *The Frog Book*, Ditmars; *The Reptile Book*, Ditmars; *Economic Zoölogy*, Osborn, from page 311 to end; *Useful Birds*, Forbush; *Economic Value of Birds to the State*, Chapman, N. Y., F. F. and G. Com.; *Birds of Eastern North America*, Chapman, pp. 6-7; *Bird Life*, Chapman, Chap. I, and note; *Birds of Eastern North America*, Reed, pp. 12-14; *National Geographic Magazine*, November, 1916, and May, 1918; *Domesticated Plants and Animals*, Davenport; *Birds in their Relation to Man*, Weed and Dearborn.

SUMMARY

I. Fishes.

1. Food for man (5000 species).
2. Food for aquatic animals.
3. Fertilizer.
4. Oil.
5. Glue, isinglass.

II. Amphibia.

1. Destroyers of insects.
2. Food (frog legs).

III. Reptiles.

Harmful activities.

1. Venomous snakes (rattler and copperhead).
2. Venomous lizard (Gila monster).
3. Man-eating crocodiles.
4. Destroy birds' eggs and young (black snake).
5. Destroy frogs (black and garter snakes).

Useful activities.

1. Destroy insects.
2. Destroy harmful rodents.
3. Furnish food (turtle meat and eggs).
4. Furnish shell (tortoise) and leather (alligator).

IV. Birds.

1. Destroy insects.
2. Destroy weed seeds.
3. Food (flesh and eggs).
4. Feathers.
5. Companions.

How protect birds?

1. Obey and enforce protective laws.
2. Restrain their enemies.
 - (a) Plume hunters and game hogs.
 - (b) Cats, red squirrels, snakes.
 - (c) Cooper's hawk, sharp-shinned hawk, horned owl, English sparrow.
3. Preserve forests and trees.
4. Provide winter food and summer homes.

V. Mammals.

1. Food, meat and milk (ungulates)

meat (various forms except dog and cat groups).
2. Clothing, wool (sheep, goat, camel, llama).

fur (rodents and carnivora).

leather (ungulates, etc.).
3. Various products.

From whale: oil, wax, "whalebone," ambergris.

From elephant: ivory.

From various mammals: horn and bone.
4. Transportation.

Horses, oxen, camels, reindeer, dogs, goats, llamas, water buffalo.
5. Pets.

Dogs, horse, cat, etc.

"Domestic animals."
6. Harmful mammals.
 - (1) Large carnivora (lion, tiger, wolf).
 - (2) Rodents (rats, mice, squirrels).

waste foodstuffs.

transmit disease.

CHAPTER XLIX

BIOLOGY AND AGRICULTURE

Vocabulary

Pulverizing, making into powder.

Tillage, plowing, cultivating, harrowing, or hoeing the soil.

Retain, to hold.

Diminishing, making smaller.

Civilization rests upon the soil. In so far as our knowledge enables us to use the soil to best advantage, only so far can we advance in population, wealth, and national growth. At present we are far from realizing our greatest agricultural efficiency, as the following tabulations show.

China	supports	3500	people	per	square	mile.
Japan	"	2000	"	"	"	"
Belgium	"	300	"	"	"	"
United States	"	30	"	"	"	"

As to crop yields we compare as follows,

	<i>Maximum yield per acre</i>	<i>U. S. yield per acre</i>
Potatoes	500 bushels	96 bushels
Wheat	50 "	14 "
Corn	100 "	28 "
Oats	100 "	32 "

Evidently there is much to be learned before we shall obtain the best results from our national resources.

Soil Formation. Soil is formed from rock by the action of heat and cold, water and ice, bacteria and protozoa, which are all engaged in pulverizing its particles and adding to it organic matter and nitrogen compounds. Proper tillage admits air for plant use

and carbon dioxide to act chemically on the soil; it loosens the soil grains to permit easy root growth and exposes new stores of plant food for them to absorb. Loosening the top layers by frequent tillage also forms a protective layer which retains water.

Soil Composition. Plants can obtain oxygen, hydrogen, and carbon from air and water, but must depend on the soil for all compounds of nitrogen, phosphorus, and potassium which are just as essential in the making of protoplasm.

To be fertile, a soil must contain compounds of these elements in soluble form, available for plant use. The average soil contains a supply of potassium compounds sufficient for 2000 years, phosphorous compounds to last for 130 years, but nitrogen compounds only sufficient for 70 years' use. Yet nitrogen compounds are more essential and used in greater quantity than either of the others.

Evidently the supply of nitrogen is the limiting factor in determining how long a soil will remain productive; hence its return to the soil is one of the greatest problems in agriculture.

Maintaining the Soil. Every crop removes these essential elements from the soil and erosion may rob it of as much more, so man has learned to replace the removed substances by, 1. fertilizers, 2. nitrifying bacteria, 3. crop rotation.

1. *Fertilizers* obtain potash as potassium chloride and sulphate, largely from German deposits. Phosphorous compounds are obtained from bone ash and the phosphate rock found in California and Florida. Nitrogen is supplied to the soil by

(a) Natural manures.

(b) Nitrate of soda from Chile.

(c) Slaughter house wastes.

(d) Ammonia compounds from coal distillation.

(e) Action of nitrifying bacteria.

A complete fertilizer should supply all three elements, but as the soil often has enough of one or two, this is sometimes unnecessary and analysis of the soil is the only sure way of determining its needs.

2. *Bacteria*, found in nodules on the roots of clover, peas, al-

falfa, and lentils, have the power of converting the free nitrogen of the air into nitrogen compounds, available for plant use, so clover crops actually benefit the land so far as nitrogen is concerned.

Other bacteria help in decay of organic matter and return it to the soil in useful forms; all dead tissue and natural manures are acted upon in this way.

3. *Rotation of crops* merely applies what has just been said. The farmer cannot use the same field for the same crop, year after year, without removing the special soil compounds which that crop requires and thus diminishing his return. He therefore varies his crop so that clover or peas shall have a chance to replace nitrogen compounds which wheat or corn may have removed. He also alternates between crops that require hoeing and those that do not, so that the soil may benefit by the different methods of cultivation. Often the clover crop is plowed under so that the organic matter as well as the nitrogen is returned to the soil.

Plant Breeding. Not only does biology bear upon soil conditions but also upon all that relates to seed planting, germination, and growth. Especially is this true in the matter of testing and selection of seed and in crossing and breeding of new varieties. A glance at any seed catalog will show the great advances that are being made by applying biologic methods to bettering the varieties of plants.

In this same connection, all other methods of plant propagation are concerned. Cuttings and grafts, pollination, transplanting, and pruning all involve the use of biological information.

In 1900 the British Millers Association decided that the wheat that was then raised in England was so unsatisfactory that they engaged Prof. R. H. Biffen of Cambridge University to try to improve the quality.

Professor Biffen obtained seed of all the different wheats, which had any one desirable characteristic, such as stout straw, full heads, immunity to rust, or resistance to cold weather. These he raised separately, and cross-pollinated by hand, combining their desirable features, till after years of effort, selection, crossing,

and rejection of the unfit, he developed the present English wheat which combines nearly all the characteristics which the millers demanded.

In the United States, Mr. Burbank stands at the head of our plant breeders. By cross-breeding and rigid selection he has developed many valuable new species. His improved potato adds \$17,500,000 to the annual income of the farmers of the United States. He has increased the yield of some kinds of corn twenty fold. He has improved known fruits in their quality, hardness, or resistance to insects. He has developed several new fruits, either from wild species or by crossing. Many large and beautiful flowers have been produced, such as the mammoth poppy with a diameter of ten inches, and the delicate shasta daisy. One of his most notable successes has been the spineless cactus, which is now available as cattle fodder in regions where it is difficult to provide food for stock.

Burbank's work is merely a very noted example of the application of biologic laws to plant improvement, such as is being carried on by all seedsmen and all intelligent farmers and gardeners. When we save seed from our best or earliest plants, keep them separate from less satisfactory kinds, and plant their seed again, we are following in the footsteps of these great breeders, and utilizing the same laws of inheritance.

By similar methods, practically every plant that man cultivates has been improved and developed into forms that better serve his purposes.

Plant Protection. Biology comes to the aid of the farmer in his struggle against plant disease. Moulds, rusts, blights, and bacterial attacks all have to be met by proper treatment of seed with formalin, or the plant itself with fungus-killing sprays like Bordeaux mixture.

Insect enemies and the means of checking them open another chapter of farm biology. Here also belongs the study of useful birds and their enormous value as insect destroyers.

Animal Husbandry. Principles of biology are also applied to animal raising, their care and feeding, selection and domestica-

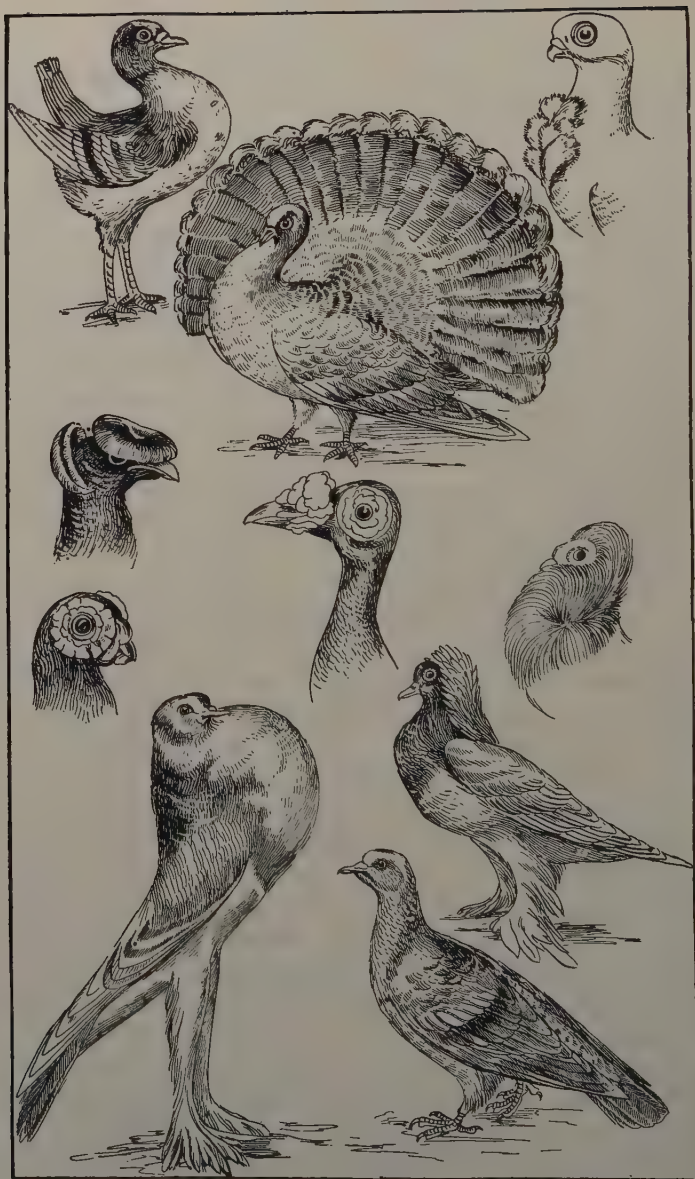


FIG. 153. Various races of pigeons, all probably descended from the European rock dove, *Columba livia*, shown in lower right hand corner. (After Haeckel.) From Kellogg.

tion. Especially is this true in the case of animal breeding for improved varieties. Here are involved selection, inheritance, and cross-breeding.

By following well-known biologic methods man can select almost any group of desirable characteristics and produce a breed possessing them. As evidence of this, note the numerous and widely different types of horse, cow, or dog that man has thus developed.

In early years England had three general types of sheep, —



FIG. 154. Typical American Merino ewe, a highly specialized breed of sheep, with fine, close-set wool. (After Shaw.) From Kellogg.

some hornless, some with fine wool, and some producing good mutton. By long and careful breeding and by rejecting all unsatisfactory animals for propagation, they now have several races that combine in a large degree all these useful features.

In similar ways we have different breeds of cows for different purposes, the Jersey producing as much butter fat as ten ordinary cows, the Holstein for large milk production, and the Hereford for beef.

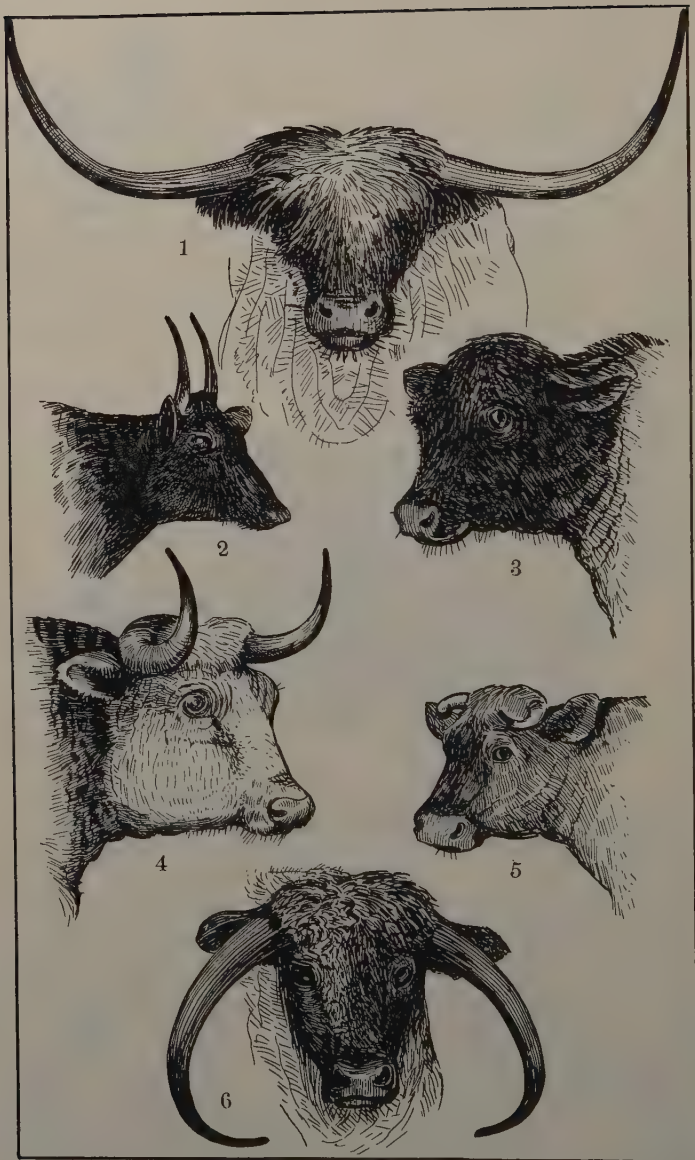


FIG. 155. Heads of various British breeds of domestic cattle, showing variations in shape of head and condition of horns: 1, Highland Scot; 2, Irish Kerry; 3, Aberdeen Angus; 4, Hereford; 5, Jersey; 6, Long-horned Midland. (After Romanes.) From Kellogg.

Horses for trotting, running, draught, or mere appearance, are bred and selected and their pedigrees so carefully recorded that many a trotter can trace his ancestry much farther back than most human aristocrats. The advantage lies with the horse in another way, since his ancestors were valued because they could *do* something well, and not merely because of the accident of birth.

Bacteria on the Farm. Care of milk on the farm has been already mentioned, but in cream, butter, and cheese as well, the farmer is using some bacteria and opposing others. The characteristic flavors and odors of butter and cheese are due to useful bacterial action, while the spoiling and decay of these products is due to attack of others.

Bacteria are working also in the preparation of ensilage and the "curing" of meats and tobacco. In fact if you will look back over your work you may be surprised at the extensive rôle of bacteria as farm laborers.

Here are some of their activities, good and bad:

They aid in decay of organic matter for fertilizers.

They cause decay of valuable foodstuffs.

They help return nitrogen to the soil.

They cause many plant and animal diseases.

They aid in all dairy processes.

They spread disease by way of milk and other foods.

They help in producing ensilage.

They aid in curing meats, flax, and tobacco.

There is no branch of industry so important, and none so closely associated with biology as the industry of agriculture. Most of the material found in the chapters on economic biology both of plants and animals, together with much under forestry and general conservation methods, bears directly on this fundamental occupation.

COLLATERAL READING

Agriculture for Beginners, Burkett, Stevens and Hill; *The Fertility of the Land*, Roberts; *Soil Fertility and Permanent Agriculture*, Hopkins; *Principles of Agriculture*, Bailey; *Farmers for Forty Centuries*, King; *Fertilizers*, Voorhees; *Practical Agriculture*, Wilkinson; *First Book of Farming*, Goodrich; *Cyclopedia of American Agriculture*, Vols. II and III;

Milk and its Products, Wing; *Types and Breeds of Farm Animals*, Plumb; *Commerce and Industry*, Smith, pp. 20-85; *Principles of Breeding*, Davenport; *Domesticated Animals*, Shaler; *First Principles of Agriculture*, Goff and Mayne; *Science of Plant Life*, Transeau, pp. 217-232.

PLANT BREEDING

Elementary Studies in Botany, Coulter, pp. 326-339; *New Creations in Plant Life*, Harwood, entire; *Origin of Cultivated Plants*, De Candolle, entire; *Experiments in Plants*, Osterhout, pp. 409-453; *Botany for Schools*, Atkinson, pp. 455-478; *The Living Plant*, Ganong, pp. 426-444; *Species and Varieties (Mutation)*, De Vries, entire; *Domesticated Animals and Plants*, Davenport, entire; *Elementary Biology*, Peabody and Hunt, pp. 105-125, 241-300.

DOMESTIC ANIMALS

Elementary Zoölogy, Davenport, pp. 420-450; *Domesticated Animals and Plants*, Davenport, entire; *Economic Zoölogy*, Kellogg and Doane, pp. 321-334; *Pet Book*, Comstock, entire; *Farm Bulletins*.

SUMMARY

1. Importance of agriculture.
2. Lack of efficient development.
3. Soil formation.
4. Soil composition:
 - Potassium compounds.
 - Phosphorous compounds.
 - Nitrogen compounds.
 - Organic matter or humus.
5. Soil maintenance.
 - By fertilizers.
 - By bacterial action.
 - By crop rotation and cultivation.
6. Plant breeding.
7. Plant protection.
 - From insect enemies.
 - From fungus attack.
8. Animal husbandry.
 - Care and feeding of stock.
 - Breeding new forms.
9. Bacteria on the farm.

CHAPTER L

THE ECONOMIC IMPORTANCE OF FORESTS

Vocabulary

Erosion, washing away of soil.

Retention, holding.

Girdling a tree, cutting off a ring of bark and cambium to kill it while standing.

Re-forestation, scientific replacement of trees when cut.

The great importance of forests is little appreciated. When we are told that they occupy 35 per cent of the area of the United States and that lumbering is our second largest industry, still their most important services are overlooked.

VALUE OF FORESTS

Control of Water Supply. The most important service rendered by forests is in regulating water supply. The forest area acts like an enormous sponge absorbing the heavy rainfall, in its layer of humus. This secures the following important results.

1. Prevents floods and causes steady flow.
2. Prevents drouth by storing water in the wet season.
3. Prevents washing of soil into rivers.
4. Keeps rivers at uniform level for transport.

The effect of forests in this regard can only be appreciated when compared with an area which has no forest protection and is subject to heavy rainfall, such as the Bad Lands of Dakota. Here the water runs off at once in floods, while between rains, the land is almost a desert, due to drouth, and the rivers are so filled with mud and so changeable in levels as to be useless for commerce or power.



FIG. 156. Map showing distribution of the National Forests (1910). This total area is greater than that of England, Ireland, Scotland and Wales. From Smith's *Commerce and Industries*.

Benefit to Soil. The early settlers regarded the forests as the enemy to agriculture and so they were, in so much as some clearings had to be made to make room for the farms, but in a larger sense, the forests are a distinct benefit to the soil. Erosion, the washing away of soil by rain, is one of the worst enemies of agriculture and this is prevented by the forest areas, whose roots hold back the earth and whose leaves protect the surface. Fur-

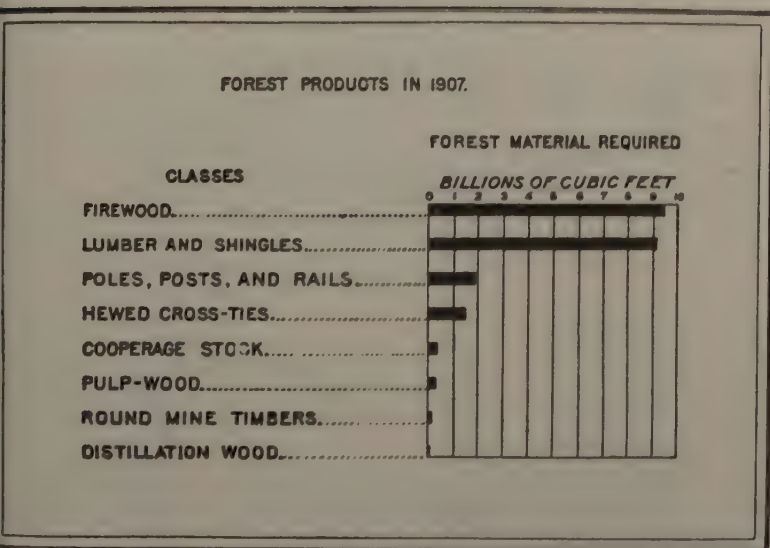


Fig. 157. Uses of Lumber. From Smith's *Commerce and Industry*.

thermore, the organic matter (humus) which collects on the forest floor, supplies an essential element to all fertile soils.

In some areas, the forests perform another function in preventing the spread of wind-blown sand over fertile areas which are thus saved for use.

Effect of Forests on Climate. While this may not rank with the two preceding in importance, yet it is certain, that by its retention of moisture, forests do modify the climate over large areas and apparently influence local rain-fall as well. To a less

extent, forests affect climate by their action as a protection from wind or sun.

Forests as Home for Birds and Game. This is a matter often overlooked, but when we recall the enormous economic value of birds, and realize that they depend largely on the forests for their home, the importance of this factor is apparent. As a home for fur-bearing animals, game, and fish the forests also are important to man in many relations little realized.

Forest Products. When the economic value of forests is mentioned one naturally thinks of the lumber and other direct products as the most important. While not equal to those already mentioned, the variety and value of the manufactured forest products is enormous.

Time will not permit discussing each in detail so, in the tabulation which follows, some of the most important items are mentioned.

FOREST PRODUCTS

1. Timber products.

Lumber	Laths
Shingles	Veneers
Railroad ties	Poles
Mine timbers	Ship timbers

2. Paper (spruce, poplar, etc.).

3. Fuel (wood, charcoal, coal).

4. Naval stores (pitch, tar, turpentine, resin).

5. Tanning material (hemlock and oak bark).

6. Maple sugar.

7. Spruce gum.

8. Distillation products

	Uses
charcoal	fuel
lamp black	ink
tar	tar paper, wagon grease, and wood preservation
oil	varnish, soap, disinfectants, ink
oxalic acid	dyeing, bleaching, making formic acid
acetic acid	white lead paint, dyes, and medicines
wood alcohol	varnish, solvent, dyes, denaturing alcohol, fuel, making formaldehyde, and smokeless powder
acetone	explosives, films, dyes, and solvent

NOTES ON TABULATION

1. Timber products.

- (a) U. S. produces 38,000,000 thousand feet of "soft wood" lumber per year, and 8,000,000 thousand feet of hard wood lumber.
- (b) The chief kinds are
 yellow pine from Carolina, Georgia, etc. (40 %).
 white pine from Michigan, Wisconsin, Minnesota.
 spruce and redwood from the Pacific slope.
- (c) The enormous number of trees cut may be judged when we realize that 65 % is wasted in making lumber.

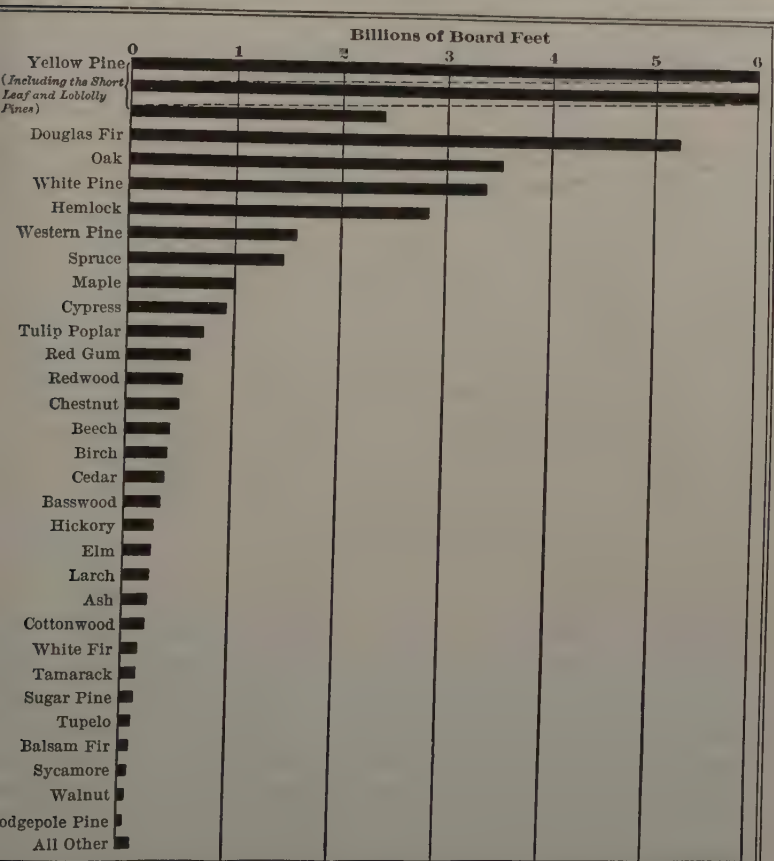


FIG. 158. Lumber production by varieties, 1910. (U. S. Forest Service.)

- (d) Railroads use 2500 ties per mile — there are about 200,000 miles in U. S. and the ties have to be replaced every seven years; this means the use of about 70,000,000 ties per year.
2. **Paper.** A single New York daily newspaper uses for paper the spruce trees from 44 acres per day.
The greatest amount of paper is made in New York, Wisconsin, and New England.
3. **Fuel.** Coal is indirectly a forest product as it is the carbon from trees of ages ago, partly decomposed under the earth by heat and pressure.
4. **Naval stores.** These are so called because tar and pitch are used in connection with ship building and cordage. The crude pitch is obtained by notching the southern pines and collecting the product which is distilled, making tar, turpentine, and rosin. U. S. exports seven times as much turpentine and ten times as much rosin as any other country. The value reaches \$36,000,000 per year.
5. **Tanning materials.** Quebracho and other tropical woods could be included.
6. **Maple sugar.** U. S. produces 50,000,000 pounds and 4,000,000 gallons of syrup per year, of which Vermont and New York supply over three-quarters.
7. **Spruce gum.** This gum forms in masses on the bark of spruces and is gathered and cleaned in the winter. Really fine gum is worth several dollars a pound.
8. **Distillation products.** Various kinds of hard wood are heated in closed iron cylinders, destructive distillation goes on, charcoal remains in the cylinders and the other products go off as vapors and are condensed and separated. We will learn more about this in chemistry. For the present notice how many products there are and for what various and important purposes they are used.

FOREST ENEMIES

Man. Valuable as they are, forests have many enemies, and strange as it may seem, one of the worst of them is man. Of course we destroy much standing timber for necessary use and for clearing for agriculture, but much more is utterly wasted in other ways. Annual growth in the United States is 7,000,000,000 feet but the annual consumption totals over 20,000,000,000 feet.

Careless lumbering, in which only a few trees are used and many destroyed, or wasteful methods, by which only one-fourth of the cut timber ever becomes lumber, are some of man's methods of attack. Cutting hemlock and using only the tan bark, leaving

the stripped timber a total loss and danger in case of fire, is another barbarous waste for which man is responsible.

Fire is one of the forests' worst foes and except for lightning, man is the author of them all. Sparks from locomotives and camp fires of careless hunters account for some which start accidentally, while grazers and berry pickers start fires on purpose to help their crops, and men, clearing land, often lose control of their fires and cause great destruction. In 1915 there were 40,000 fires, covering 6,000,000 acres, or over 1 per cent of all forests in United States, which caused a loss of \$7,000,000 and many lives. During the same year 2½ million were spent for forest protection or only one-third the year's loss.

Insect Enemies. In our study of insects, the damage which they do to crops was mentioned, and the forest crops are no exception. The saw fly, bark beetles, gypsy moth, tent caterpillar, and tussock moth are some of the most harmful, and, unlike the orchard pests, the extent of the forests makes spraying impossible. The birds are almost our sole protection against these forest enemies, though toads, snakes, and ichneumon flies do their share.

Fungus Enemies. Whenever we see a shelf fungus on a tree we may be sure that tree is doomed unless help is provided. But the most damage is done by less conspicuous forms, such as the rusts and blights, of which the chestnut blight is a notable example. (Not only are the trees destroyed but their lumber is ruined by fungi, both in standing timber and often after it is cut and piled.)

Weather Conditions. Despite their great strength, trees often fall victims to wind and snow, and in many regions great strips are blown down by tornadoes making the almost impassable "windfalls" which later, when dead and dry, furnish ideal fuel for forest fires. Sleet storms destroy many buds and even large branches, especially if followed by severe winds, and thus damage or kill many valuable forest trees.

Grazing Animals and Others. Large herds of cattle or sheep often damage forests by trampling on the young trees and by

feeding on the limbs and leaves. Mice, porcupines, and rabbits often girdle the trees by eating their bark, and some little damage is done by birds and squirrels which eat their seeds.

FOREST PROTECTION

The value of the forests of the United States is evidently very great, but only recently have efficient means been taken to protect them.

Legal Protection. To begin with, one of the most important means of protection lies in the hearty coöperation of every citizen in observing and enforcing the present forest laws as to fire prevention and proper lumbering.

Careful Lumbering. The average lumberman harvests his crop, but does not plant another. Hence we face the ever rising cost of lumber, whereas, if the timber annually cut is regulated so as not to exceed the year's growth the forest will continue to produce like any other crop.

Reforestation. Another means of protection consists in replanting, either by setting out small trees, or cutting only mature ones and leaving young and seed-bearing trees so that nature can attend to the replanting.

Forest Reserves. The Government has established large forest reserves which are kept by the Nation to protect drainage for irrigation, to supply grazing areas, and provide timber under supervised cutting. (See p. 496.)

Forest Rangers. To protect these enormous tracts of Government forest from fire or theft, there is provided a body of expert Forest Rangers under Government control.

These men patrol the forests, report and prosecute theft, and organize to fight forest fires before they may get out of control. This work has saved millions of dollars and many lives in the line of fire prevention alone.

Forestry Schools. Furthermore, there are established Forestry Schools at Cornell, Michigan, Syracuse, Yale, and elsewhere, in which the scientific methods of lumbering, planting, and pro-

tection are taught. For those unable to attend these institutions, many bulletins and other publications are available from state and national governments, giving valuable information regarding this important source of our natural wealth.

The farmer who would cut down his apple trees to gather the fruit, or who harvested a crop without planting another, would be considered insane, yet the treatment of our forest resources amounts almost to this. The sooner we realize the fact that a forest is a crop to be tended and gathered, planted, and protected like any other, the sooner our lumber, paper, and other products will cease to increase in cost.

TIMBER STRUCTURE

A great deal of the value of lumber depends on one of three factors, its durability, strength, or appearance. These in turn depend upon the minute structure of the tree stem and though this was discussed in Chapter XI, it needs to be recalled in this connection.

A woody stem is made up of wood fibers and ducts (tracheids in the evergreens). These are arranged in annual rings caused by larger ducts forming in the spring, and fewer and smaller ones in autumn and winter.

“**Grain.**” Evidently a board cut from such a stem will have alternate layers of harder and softer tissue which cause the “grain” seen in most woods. If the board is cut from near the side of a log, few annual rings will show on the surface, their *sides* will be exposed for wear and will give a grain figure like (A). If the board be cut near the center of the log (B) *all* the annual rings will show and their *edges* are exposed for wear which makes the lumber more durable and less liable to sliver up. The former (A) is known as “bastard sawed” and the latter (B) as “rift sawed” lumber. As a log is cut up, the first boards will be bastard grain, then as the center is approached, more and more nearly rift grain, and finally bastard cut after the center is passed. Obviously there are more bastard than rift boards and hence the latter are more expensive, as well as more durable.

Quarter Grain. In all stems there are pith rays extending from pith to bark, but only in oak, maple, sycamore, and a few others are they large enough to affect the grain of the timber. Since these pith rays run toward the bark, a board cut at (C) would show only their cut ends which would be too small to notice, whereas, if the board be cut at (D) the pith rays will be cut more or less sidewise and will show as the plates or flakes which are characteristic of "quartered oak," giving it its beauty and value.

In order to get as many boards as possible showing this flake

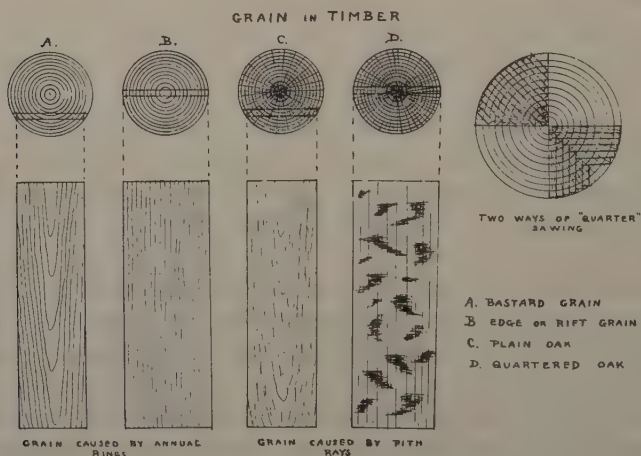


FIG. 159. Diagram showing cause of grain in timber and various methods of sawing so as to take advantage of the grain.

grain (side of pith ray) the logs are sometimes cut in quarters and then sawed from the center outwards so as to show the sides of as many pith rays as possible — hence the term "quarter sawed" or "quartered oak." The bastard cut oak, which shows only the annual ring grain (as in A) is sold as "plain" oak and while almost as durable is not nearly as handsome.

Heart and Sap-wood. As a tree grows larger, only the outer annual rings carry sap in their ducts, while the inner region becomes practically dead, its only function being support. This

center part is called the "heart wood" and is often darker in color and more durable than the outer, live region or "sap-wood." The heart of a tree may totally decay and yet cause the tree no harm other than weakening its strength, but the sap-wood is necessary to the growth of the tree and may even keep it alive when the bark has been girdled.

Shrinkage and Warping. Fresh-cut timber contains much water and the process of drying, called "seasoning," has to be thoroughly accomplished before it can be used. This is because lumber shrinks as it dries and no amount of nailing will hold poorly seasoned boards together. As a board dries there is a tendency for the side nearest the bark to shrink fastest causing the board to curve away from the center, or "warp." Unless the lumber be properly piled and dried it may be rendered unfit for use.

Hard and Soft Woods. Trees can be grouped in two classes, those with broad leaves, which are shed annually (maple, oak) and those with needle-shaped leaves, which are not all shed at one time (pine, spruce). The former produce "hard wood" lumber and the latter "soft wood," though some broad-leaved trees have lumber that is very soft (basswood, willow) and some pines produce "hard pine" lumber, which nevertheless, is classed as a "soft wood."

"Knots" in lumber are places where a branch has been broken off and the scar covered by additional annual rings. If the wound healed at once and no rot commenced, the knot is tight and does not harm the lumber so much, but if the healing was incomplete, a loose knot results and a knot-hole in the board is the result.

A tree grows in height only at the tips of new branches; it grows in thickness layer by layer, over all parts, hence a nail driven into a tree will always remain at the same height from the ground, but will be covered, in time, by the growth in thickness.

Street Trees. In proportion to their number, trees are more valuable in the city than in the forest. Shade trees add to the cash value of property in the same way as do wide streets, good pavements, and favorable location. A city always is proud of handsome trees and shady streets, but often there is little care

exercised in their planting or maintenance. If quick growth and immediate results are wanted, soft maples or poplars are used, but these are short lived and rather easily broken by storms. Elms and hard maples, on the other hand, grow slowly, but are sturdy and live to great age.

City trees require special protection as they are especially valuable and are not living under natural conditions. Insect attacks can be overcome by proper spraying; damage by horses and traffic can be prevented by guards around the trunks; suitable laws can be enforced to protect from damage by careless linemen who cut out the tops to pass their wires; sidewalks and curbs can be kept from injuring the roots; and "surgical" treatment should be used when rot or injury makes wounds in any part.

COLLATERAL READING

Elementary Studies in Botany, Coulter, pp. 419-431; *A First Book of Forestry*, Roth, entire; *Care of Trees*, Fernow, entire; *Handbook of Trees*, Hough, look through; *Nature Study and Life*, Hodge, pp. 365-391; *Practical Biology*, Smallwood, pp. 376-388; *Principles of American Forestry*, Green, entire; *Trees of Northern United States*, Apgar, look through; *Commerce and Industry*, Smith, pp. 182-208; *Our Native Trees*, Keeler, look through; "*American Forestry*," a monthly periodical.

SUMMARY

Value of Forests.

1. Control of water supply.
2. Benefit to soil, humus.
3. Effect on climate, wind protection.
4. Home for birds and game.
5. Forest products (see tabulation).

Enemies of the Forests.

1. Man, through careless lumbering, fires, etc.
2. Insect enemies.
3. Fungus diseases.
4. Weather conditions, sleet, frost, snow.
5. Grazing and other animals. Rodents.

Protection of Forests.

1. Laws, enforced and supported by people.
2. Careful lumbering.
3. Reforestation, planting, etc.

4. Forest reserves held by the Government.
5. Forest rangers to protect reserves.
6. Forestry schools, to instruct people.

Timber Structure.

1. Grain, due to annual rings, bastard and rift, due to pith rays, quarter and plain.
2. Heart and sap wood.
3. Shrinkage and warping.
4. Hard and soft woods.
5. Knots.

Street Trees.

1. Value.
2. Most useful kinds.
3. Means of protection.

CHAPTER LI

TOBACCO AND TABLE BEVERAGES

Vocabulary

Nicotine, a harmful ingredient of tobacco, an alkaloid narcotic.

Acrolein, an irritating substance in tobacco smoke.

Caffein, an alkaloid found in tea, coffee, and cocoa.

Cocaine, an alkaloid from leaves of coca plant. No connection with cocoa.

Morphine, an alkaloid from the opium poppy juice.

The damage done by alcohol and tobacco are often dealt with in the same chapters and spoken of together, as if they had much in common. This is unfortunate, for young people, seeing men little harmed by use of tobacco, will assume that alcohol is no worse, and come to very wrong conclusions.

Tobacco does harm enough, wastes resources enough, but we ought not to let alcohol assume any comparison of their relative danger. This is not to excuse the use of tobacco, but to prevent young persons from concluding that one is no more harmful than the other, merely because they are often spoken of together. A comparison of this chapter with the one on alcohol will make the matter sufficiently plain.

Tobacco. It is well known that protoplasm in a young plant or animal is more easily injured than when it has attained full growth. The seedling plant is more easily killed by frost or heat; the chick is harmed by exposure that would not be felt by the hen; the human infant is injured by various things which would not affect the adult at all. This is not alone because of the difference in size of body, but the growing active protoplasm is much more sensitive than when it reaches maturity, and therefore is much more seriously affected by stimulants and narcotics.

Herein lies the chief biologic argument against the use of tobacco. Tobacco contains a harmful alkaloid, nicotine, and also produces when burned, carbon monoxid, which is a poisonous gas. In addition if the smoke is inhaled, a substance called acreolin, together with the smoke particles, increases the irritating effect.

If used by boys who have not attained the full physical maturity of twenty years or more, these substances produce numerous and serious results which should at least postpone the use of tobacco till later life.

Tobacco is narcotic in effect; narcotics tend to decrease bodily efficiency and hinder growth. The physical effects, while not to be compared with the ravages of alcohol, are nevertheless important and should be noted.

Irritation to Mucous Membranes. Smoking certainly irritates throat and lungs, especially if the user "inhales." This opens the way for germ attack in addition to the harm done to the tissues by smoke and acreolin. The eyes are also irritated especially when one smokes and reads at the same time.

Effect on Endurance. Any narcotic interferes with nerve control, especially of heart and lungs. That this is the case with tobacco, has been abundantly proven by experiment. For this reason, no trainer permits smoking by members of his team, knowing well that endurance and "wind" cannot be developed when tobacco is used. The United States forbids its use at West Point and Annapolis because of its harmful effects, both physical and mental. Figures obtained from six leading colleges show that of those who "made the team" just twice as many were non-smokers.

Effect on Growth. In some cases the use of tobacco seriously affects digestive processes and in its early use the stomach usually revolts at its presence. The effect of excessive smoking may even extend to the vital activities of protoplasm and actually "stunt the growth" of various organs. This is common where it is used when very young.

Effect on Mental Development. Many investigations at different schools and colleges have thoroughly proven that the use

of tobacco affects the brain enough to impair scholarship. Dr. Meylan, physical director at Columbia, reaches these conclusions:

1. Smokers averaged eight months behind non-smokers in their advancement.
2. Scholarship standing of smokers was distinctly lower.
3. Use of tobacco by students is closely associated with lack of ambition, application, and scholarship.

Another investigation shows that:

1. Smokers average lower in grades.
2. Smokers graduate older.
3. Smokers grow more slowly in height and weight.
4. 95 per cent of honor pupils are non-smokers.

Dr. Andrew D. White, who for twenty years was president of Cornell University, says, "I never knew a student to smoke cigarettes who did not disappoint expectations, or to use a common expression 'kinder peter out.' I consider a college student who smokes as actually handicapping himself for his whole future career." Dr. White was not a fanatic and used tobacco himself after he reached middle life.

In spite of such evidence boys certainly will note many successful men, perhaps their own fathers, who do not seem to be harmed by smoking, and, forgetting the difference in age, will draw wrong conclusions. Tobacco would do less harm if it were more harmful, so that its effects could be more easily traced.

For such prospective smokers there are other arguments.

1. Tobacco certainly becomes a "habit." Do you want to be "held" by a useless and probably harmful drug?
2. Tobacco is offensive to many people. Are you so selfish as to gratify your taste to the discomfort of others?
3. Tobacco decreases your personal attractiveness. The odor of breath, hands, and perspiration, the stains on fingers and teeth, do not add to your good looks.
4. Tobacco is expensive. A regular smoker spends more than he realizes on his indulgence. Don't you think you could have more fun for your money?

5. The growth and manufacture of tobacco wastes soil, labor, and money, sorely needed in productive lines of industry.

6. Smokers cause about one-fourth of the fires, both in buildings and forests. You can scarcely find a factory without its "No Smoking" signs on this account.

To quote from another authority in conclusion:

"Whatever difference of opinion there may be regarding the effect of tobacco on adults, there is complete agreement among those best qualified to know, that the use of tobacco is in a high degree harmful to children and youth."

Tea and Coffee. To a degree much less than tobacco, these beverages contain an alkaloid called caffein. As with tobacco, their use is certainly not wise for the young. With adults, moderate indulgence may do no harm or may even be beneficial, though this is a matter which every person must decide for himself.

Neither has much food value, both are rather costly, and both tend to become habits. On the other hand they sometimes seem to soothe the nerves (which ought not to need soothing), or to permit one to continue work when nearly tired out, which also is a rather doubtful benefit.

Cocoa and Chocolate contain less caffein and a great deal of fat, hence are real foods. More people should learn to properly prepare them and then tea and coffee would be less used, with benefit to all concerned.

It seems almost unnecessary to say that no medicine or beverage containing alcohol, opium, morphine, chloral, cocaine, or any of their derivatives should *ever* be used except by advice of a reputable physician. The awful danger of forming a "drug habit" in this way has led to stringent laws, which we should all help enforce.

TABULATION OF SOME COMMON DRUGS

Stimulants	Narcotics
Alcohol, slight first effect	Alcohol, general effect
Caffein in tea, coffee, and cocoa	Nicotine
Strychnine	Opium, morphine, etc.
Nux vomica	Chloral
Gentian	Cocaine, heroin, etc.
Quinine	Codeine

COLLATERAL READING

A Handbook of Health, Hutchinson, pp. 89-93, 103-107; *The Human Mechanism*, Hough and Sedgwick, pp. 357-362, 377-379; *Applied Biology*, Bigelow, pp. 551-553; *The Next Generation*, Jewett, pp. 136-144; *Applied Physiology*, Overton, see index; *General Physiology*, Eddy, see index; *Principles of Health Control*, Walters, see index; *Civics and Health*, Allen, pp. 363-368; *Elementary Biology*, Peabody and Hunt, Pt. II, pp. 75-81.

SUMMARY

1. Comparison of alcohol and tobacco.
2. Tobacco. *Physical objections to its use.*
 Sensitiveness of growing protoplasm.
 Smoking exposes to nicotine, carbon monoxide, acreolin, etc.
 General narcotic effect.
 Irritation to mucous membranes.
 Reduces endurance.
 Interferes with growth and digestion.
 Seriously impairs mental development and scholarship.
Social objections to its use.
 It becomes a useless habit.
 It is a selfish habit, because offensive to many.
 Decreases personal attractiveness, odor, stains, etc.
 Unnecessary expense.
 Wastes soil, labor, and money in its production.
 Danger in causing fires.
3. Tea and coffee.
 Contain caffein.
 Very slight food value.
 May harm digestion or nerves.
 Certainly not good for young people.
 Unnecessary expense.

4. Cocoa and chocolate.
Contain little caffeine and much fat.
Useful as foods.
5. Coco-cola and similar drinks.
May contain harmful alkaloids.
Seems to become habitual.
Expensive.

CHAPTER LII

ALCOHOL IN RELATION TO BIOLOGY

Vocabulary

Magnitude, size or importance.

Detriment, harm.

Acceleration, speeding up action.

Excessive, too great.

Morbid, abnormal.

Pre-disposition, tendency toward.

Potent, powerful.

Therapeutics, curative medicine.

The chemist would say that "alcohol" is one of a number of similar compounds, containing carbon, hydrogen, and oxygen in the proportions C_2H_6O and would insist that we call it "ethyl alcohol" or "grain alcohol" to distinguish it from wood alcohol, glycerine, and many other similar forms. The physiologist or physician would tell us that it is a narcotic poison in its action on the tissues, disturbing especially the nervous system.

The reason that this substance demands a chapter in a biology text is that man, from the earliest times, has used this drug because of its intoxicant effects, until now its bearing upon the development of the human race has become one of the greatest biological problems.

Alcoholic beverages may be classed roughly in three groups:

1. Beer (2-5 per cent alcohol) made from fermented barley.
2. Wine (15-20 per cent alcohol) from fermented fruit juices.
3. Whiskey (30-50 per cent alcohol) from either source, but distilled to increase its strength.

In ancient times before modern methods of malting and distilling were invented, wine was a rare and comparatively unim-

portant drink, but now, both the amounts used and the alcohol contained, have so increased that alcoholic liquors are a biological question of the first magnitude. In the discussion that follows it must not be forgotten that alcohol is an indispensable chemical substance, used as a solvent, preservative, and raw material in numerous industries. These are matters that concern the manufacturing chemist, while biology has to do only with its effect when used as a beverage by man.

Physical Effects. In the first place alcohol, although oxidized in the body, cannot be classed as a food, yet is often so called by people who should know better. A food is "a substance which when assimilated in the animal body builds tissue or produces energy without harming the organism." Alcohol harms the organism in various ways as will be shown, hence cannot be classed as a food.

Alcohol is chiefly oxidized in the liver and the heat is lost by the rush of blood to the skin (Atwater). This oxidation produces uric acid which overworks the liver and kidneys, to the detriment of both (Beebe).

Dr. Irving Fischer of Yale says, "These heat values cannot be expended without at the same time poisoning the system with alcohol, so it is not even technically correct to count the heat value of alcohol as such."

Dr. Von Bunge, chemist of University of Basel says, "Alcohol produces energy (heat) but increases the loss of heat still more; the net result being a lowering of temperature; the feeling of warmth is an illusion due to narcotic action on the nerves."

The same authority also says, "Beer does contain small amounts of dextrine and sugar but we already eat too much of these, and supplied by beer, they are fabulously expensive; beer does not promote digestion."

Despite this claim that alcohol is a food, no one really thinks of using it for nourishment, but rather because of its narcotic effects on the nerves. Opium and phosphorus are also oxidized in the body, but no one claims food value for these poisons, and alcohol belongs in the same class.

Alcohol, then, is not a food, because

1. It produces a net loss of energy, though oxidized.
2. It does not build tissue, but poisons it.
3. It furnishes its small apparent energy at great expense.

Effect on Nutrition. Alcohol withdraws water from all food-stuffs and acts chemically on proteid, exerting a hardening action in both cases and hindering the work of the digestive fluids. In the same way it hardens and irritates the tissues lining the alimentary canal, especially the walls of the stomach, where it always interferes with normal action, and may cause serious disease. Alcohol certainly increases the flow of digestive fluids and its medicinal use was based largely on this effect until it was found that the abnormal flow caused a lack of fluids later, and that glands that had been "stimulated" by alcohol, refused to respond to the presence of mere food.

"Acceleration of gastric action is counter-balanced by inhibitory effect of alcohol on the chemical processes of digestion."
— Chittenden.

The direct effect of alcohol is shown most plainly in its action on the liver, where, as already mentioned, it overtaxes and irritates that important organ. Over 60 per cent of deaths due to cirrhosis of the liver are cases where the disease was caused by alcoholic liquors.

Effect on Circulation. The chief effect of even small amounts of alcohol is to paralyze the vaso-motor nerves which control the blood flow and heart action.

Thus with relaxed artery walls and lessened heart regulation, the pulse is quickened, the blood is driven to the skin and mucous membranes, and the familiar "stimulant" effects are produced. Notice in the first place that this is due, not to any "stimulation" at all, but to a *deadening* of the nerve controls, and second, that, although the skin feels warm, due to the excess blood, it is actually losing heat, because so much blood has been brought to the surface.

"The general temperature is always lowered." — Macey.

Not only this, but with continuous use alcohol *keeps* the capillaries relaxed, causing reddening of the skin and inflammation of

the mucous linings, both of which favor the attacks of various diseases.

Alcohol reduces the control centers and so the circulatory organs "run away"; they are NOT stimulated. One might as well talk about stimulating a steam engine by removing the governor. Yet this is a very common error.

Alcohol is never a stimulant, but always a narcotic, producing its results by its interference with nerve control in every case. "No amount of alcohol, however given, can increase the amount of work done." — Dr. Woodhead, Cambridge University.

Aside from its interference with the normal distribution of blood and consequent pre-disposition to colds and inflammations, its excessive use may permanently harden the arteries (arteriosclerosis), or affect the heart muscles (fatty degeneration), though these are not so important from a biologic standpoint as the more general effects which even occasional use produces.

Effect on Respiration. The interference with blood regulation is particularly harmful in the lungs, causing inflammation and diminishing resistance to pneumonia and congestive diseases. At the same time connective tissue is increased and the actual lung capacity is lessened. A curious chemical result also ensues; alcohol is so easily oxidized, that it uses oxygen actually needed to release the energy from real foods. This appears to be a "stimulation" of the breathing process, when as a matter of fact, the added air is not sufficient to oxidize the alcohol alone. The final result is loss of energy from the unoxidized food in addition to the heat wasted by way of the skin, as shown above.

Effect on Excretion. This improper oxidation, and interference with blood flow and skin functions produce excess of uric acid and other wastes for the kidneys to dispose of, resulting always in impaired function and sometimes in serious disease. Rheumatism, Bright's disease, and fatty degeneration of the kidneys may be caused or encouraged by excessive use of alcohol.

Effect on Nervous System. As has been shown, alcohol's principal line of attack is by way of the nervous system and it is here that its effects are most notable and most serious. In the evolu-

tion of the nervous system the centers of control develop in this order:

1. Heart and circulation control.
2. Respiration.
3. Walking and large muscles.
4. Speech and other senses.
5. Moral and intellectual control.

The peculiar harm of the narcotic action of alcohol is, that it impairs these nerve centers in reverse order. The higher emotions, moral sense, modesty, judgment, and self-control are first attacked, and from this effect arises the awful record of alcohol as a cause of immorality and crime. Leaving the body control but little impaired and able to carry out the impulses of a disordered mind, a man will commit crimes or perform acts which he never would have thought of doing if his self-control had not been affected by this dangerous narcotic drug. Further effects of alcohol are shown when the speech and sight centers are attacked, as the thick speech and double vision of the alcoholic victim are all too familiar evidence. Next the walking and other large muscles are affected and the staggering gait and uncertain movements are observed. Finally, the breathing is interfered with, the heart action partially or wholly paralyzed, and the condition of "dead drunkenness" or even death ensues.

If the order of its effects were reversed, alcohol would not be so dangerous, because the body would then be unable to carry out the demands of the deranged brain. Unfortunately, this is not the case, and herein lies one of alcohol's greatest biological dangers. Furthermore, alcohol actually attacks the brain tissue, causing irreparable harm and producing the morbid desire for more liquor so characteristic of the victims of this awful habit. The apparent "nerve stimulation," so frequently mentioned, is merely the paralysis of sense and self-control, leaving the body to act, often more violently, it is true, but never increasing its effective energy.

"Even the feeling of rest due to slight indulgence in alcohol is caused by its anaesthetic effect upon the sense of fatigue, which is the safety valve of the human machine." — Von Bunge.

The whole case is thus summarized by Dr. Brubacher of Jefferson Medical College, Philadelphia, "Alcohol deranges the activity of the digestive system, lowers the body temperature, impairs muscular power, diminishes the capacity for mental work, and leads to actual changes in the tissues of the brain and other organs."

Alcohol and Disease. Not only does alcohol have the specific effects already mentioned but injures the general health in two ways:

1. It is a direct cause of certain diseases.
2. It lowers bodily resistance to nearly all diseases.

Examples of the first case have been mentioned in connection with the various organs, such as:

Heart diseases, enlargement or fatty degeneration.

Inflammation of the liver, "hobnailed liver."

Inflammation of the stomach, indigestion.

Insanity.

Far more important, however, is the effect of alcohol in lowering the resistance of the body to external attack, and in creating abnormal internal conditions, which make the course of many diseases more serious, though they were not *caused* by the use of liquor.

This predisposition to disease is brought about in two ways:

1. The white corpuscles, which defend us against bacterial attack, are destroyed, and the ability of the blood to provide anti-toxins is lessened.

2. By the various disarrangements of nerve control, blood and food supply, alcohol overstrains certain organs, and interferes with the action of others, so that diseased conditions are produced.

Statistics compiled by the Life Insurance Companies of the United States covering a period of twenty-five years, show some remarkable results, as follows: More than twice as many users of liquor died of pneumonia as abstainers, the ratio being 18 to 39, and Dr. Osler states that "Alcohol is perhaps the most potent of all predisposing causes of pneumonia." The same is true of tuberculosis, the ratio here being 9.9 to 21.8: that is, for every 31.7

persons who died of the disease, 21.8 were drinkers, and only 9.9 were abstainers. Or to put it still another way, if you do not use alcohol, your chance of recovery is twice as good as though you drank.

Not only in special diseases but in general health, the insurance figures show the harm of alcohol. The lives of "light drinkers" are shortened an average of four years, and that of "regular drinkers" six and a half years. In general, the death rate shows a margin of 26 per cent in favor of the non-user of alcohol. Not only is the life shortened, but the user of alcohol is ill 2.7 times as often as the abstainer, and his illnesses last 2.5 times as long; this causes not only discomfort but loss of work and money.

We have spent much time studying the prevention of typhoid and smallpox and yet alcohol kills more people than typhoid and fifteen times as many as smallpox, in this country every year. Perhaps the most awful item in this catalog of the effects of alcohol on the human organism is the fact that, throughout the United States, 26 per cent of the inmates of our insane hospitals owe their condition to the use of alcohol, either by themselves or their parents.

Mr. Arthur Hunter, the chief actuary of the New York Life Insurance Company, and President of the Actuaries Society of America, from whose reports many of these facts have been taken, sums up the case as follows:

"In my judgment, it has been proven, beyond peradventure of a doubt, that total abstinence is of value to humanity; it is certain that abstainers live longer than persons who use alcoholic beverages."

Alcohol is not a Medicine. In this connection it is well to remember that alcoholic beverages are no longer credited with any medicinal value, as shown by the following resolution, adopted by the American Medical Association, June, 1917.

"Whereas, we believe that the use of alcohol as a beverage is detrimental to the human economy; and

"Whereas, its use in therapeutics, as a tonic, or a stimulant, or a food, has no scientific basis; therefore be it

“Resolved, that the American Medical Association opposes the use of alcohol as a beverage; and be it further

“Resolved, that the use of alcohol as a therapeutic agent be discouraged.”

The United States Pharmacopoeia, the accepted guide book of medical preparations, was revised in 1917, and “whiskey” and “brandy” were struck out from its lists, which are supposed to contain all the useful drugs; “port wine” and “sherry” were left out several years ago. Dr. Harvey Wiley, perhaps the most celebrated food and drug chemist in this country, was chairman of the committee which made these changes. The present opinion of the best physicians is well voiced by Dr. J. N. Hurty, Secretary of the Indiana State Board of Health. He says, “Alcohol is opposed to the public health, for it hurts any animal organism into which it is taken. It is not a food; it does not aid digestion; it does not further the good of the body; on the contrary, it hurts.”

Alcohol and Efficiency. Apart from its disastrous effect of health, the results of the use of liquor on actual ability to do work must be considered. The loss of labor due to alcohol-caused disease equaled the work of 150,000 men per year in the United States alone under unrestricted traffic. Sobriety will increase our total efficiency as a Nation, from ten to twenty per cent, adding to the country's wealth over two billion dollars besides what would have been spent for the liquor itself. To balance this enormous total, the revenue from liquor comes to less than half a billion.

Waste of Resources. Furthermore there is great waste of food stuffs in the manufacture of liquor. The enormous amounts of corn, barley, rye, and fruits can ill be spared when the cost of living is so high. Coal and transportation facilities are also used by the liquor business to a very great extent. Every pint of beer wastes a pound of coal to make it, and other beverages in similar proportions, to say nothing of the rolling stock required to transport the raw materials and finished product. The time and skill of thousands of workmen are engaged in the manufacture and sale of liquors, which in the present shortage of labor in essential industries might be much better employed.

Since writing the foregoing chapter, the people of the United States have added to our Constitution the 18th amendment, prohibiting the manufacture and sale of alcoholic beverages. If this is properly enforced, most of the awful results of the use of alcohol will disappear. It is to be hoped that, in the future, a textbook will not have to contain a chapter on the evils of alcohol, any more than they would now on the evils of negro slavery.

The final outlawing of the liquor traffic can be attributed mainly to

The long campaign of education as to its harm.

The economic waste of materials and labor.

The reduction in business efficiency.

The physical and moral effects.

COLLATERAL READING

Alcohol and the Human Body, Horsely and Sturge, entire; *A Handbook of Health*, Hutchinson, pp. 93-103; *Physiologic Aspects of the Liquor Problem*, Billings; *Elementary Biology*, Peabody and Hunt, Pt. II, pp. 64-75; *The Human Mechanism*, Hough and Sedgwick, pp. 366-376; *The Next Generation*, Jewett, pp. 118-125, 145-152; *Applied Physiology*, Overton, see index; *General Physiology*, Eddy, see index; *Principles of Health Control*, Walters, pp. 130-153 and index; *Civics and Health*, Allen, pp. 345-362; *Bulletins of the Scientific Temperance Federation*, Boston; "Alcoholism" in *Everybody's Magazine*, 1909; *The Great American Fraud*, American Medical Association, Chicago.

SUMMARY

Introduction.

Composition, C_2H_6O . "Ethyl" or "grain" alcohol.

Character, narcotic poison. (Chloroform, ether, opium.)

Reason for study here. Its effect as a beverage.

Kinds of alcoholic beverages.

Beer, 2-5 % alcohol, made from malted barley.

Wine, 15-20 % alcohol, made from fruit juices.

Whiskey, 30-50 % alcohol, made from grains or fruits (fermented and distilled).

Proper uses of alcohol.

Physical Effects of Alcohol.

I. Alcohol not a food, because

1. Though oxidized, it produces a net loss of energy.
2. Does not build tissue, but harms it.

II. Effect on nutrition.

1. Makes food less digestible by
 - (a) Withdrawing its water.
 - (b) Hardening its proteid.
2. Action on digestive organs.
 - (a) Irritates all membranes.
 - (b) Hardens tissue of the walls.
 - (c) Causes abnormal flow of fluids.
 - (d) Irritates and overworks the liver.

III. Effect on circulation.

- (a) Interferes with nerve control of heart, etc.
- (b) Relaxes arteries and capillaries, strains heart.
- (c) Blood driven to skin, temperature lowered.
- (d) Permanent inflammation of internal organs.
- (e) Possible cause of disease.

IV. Effect on respiration.

- (a) Causes inflammation of mucous linings.
- (b) Diminishes resistance to congestive diseases.
- (c) Increases connective tissue, lessening lung action.
- (d) Robs digested food of oxygen.

V. Effect on excretions.

- (a) Causes excess of uric acid.
- (b) Overtaxes the kidneys.
- (c) May cause disease, rheumatism, gout, Bright's disease, etc.

VI. Effect on nervous system.

- (a) Paralyzes higher centers first.
- (b) Later loss of bodily control.
- (c) Actual harm to nerve tissues.
- (d) Habit formation. Insanity.

VII. Alcohol and disease.

- (a) Direct cause of heart disease, enlargement, etc.
Inflammation of liver and stomach.
Insanity. Arterio-sclerosis.
- (b) Lowers resistance by
 - (1) Destruction of red corpuscles.
 - (2) Predisposition to pneumonia, tuberculosis, etc.
 - (3) Affects length of life, illness, etc.
- (c) Alcohol is not a medicine.

VIII. Waste of resources.

Foodstuffs.
Coal.
Transportation facilities.
Labor.

CHAPTER LIII

SOME GENERAL BIOLOGIC PROCESSES

Vocabulary

Liberate, to set free.

Accomplish, bring about.

Petrified, turned to stone.

Osmosis and Life. The life of any organism depends, first upon getting food into its tissues, and second upon releasing the energy from the food after it has assimilated it. These food-obtaining processes include photosynthesis, digestion, absorption, and assimilation. All these depend upon osmosis for their accomplishment.

After the food is available in the body, its energy must be released. This requires oxidation and again necessitates osmosis for the passage of oxygen through the tissues. Oxidation liberates the energy in the food and at the same time produces waste which must be excreted. Here again osmosis is the essential process.

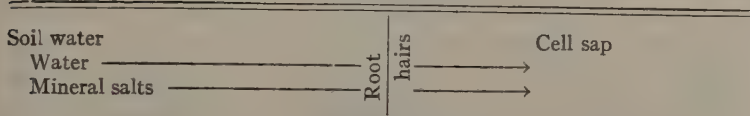
The tables which follow attempt to show this relation of osmosis to the vital processes of all plants and animals.

ESSENTIALS FOR OSMOSIS

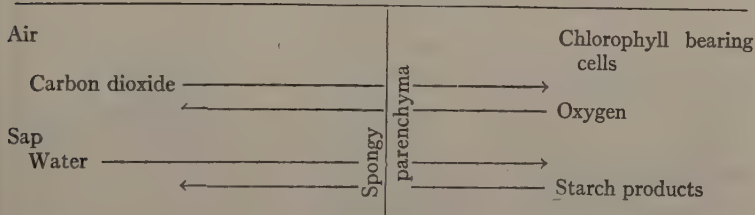
	In plant	In apparatus
Membrane	Root hair Epidermal cell, etc.	Diffusion shell
Dense liquid	Cell sap Protoplasm	Sugar solution
Less dense liquid	Soil water	Clear water

OSMOTIC PROCESSES IN PLANTS

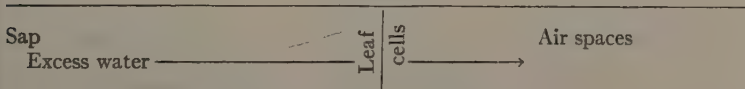
Absorption



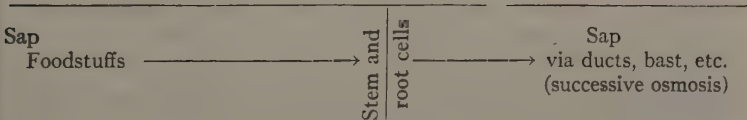
Photosynthesis



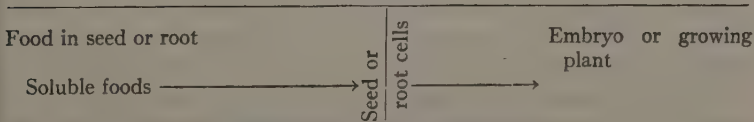
Transpiration



Transportation

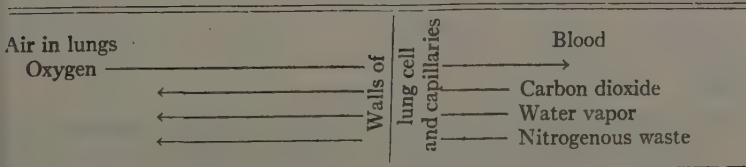


Digestion

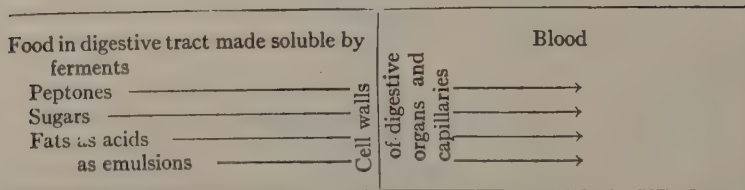


OSMOTIC PROCESSES IN ANIMALS

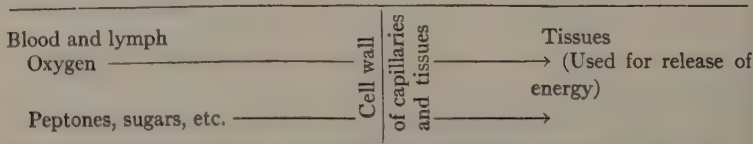
Respiration



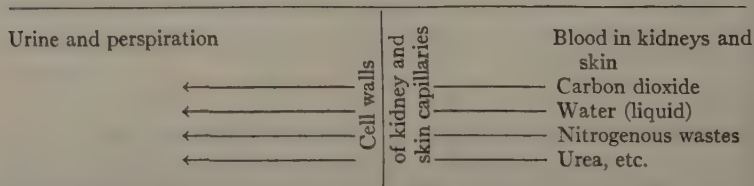
Digestion



Assimilation



Excretion



Oxidation and Life. In the process of photosynthesis, plants accomplish the manufacture of organic food and tissue out of inorganic materials, carbon dioxide, water, and mineral salts. Plants are able to do this because, by means of their chlorophyll, they can absorb energy from the sunlight sufficient to unite these inorganic materials into complex organic substances.

Animals cannot thus manufacture their own food, as they do not possess chlorophyll. It is evident that they must depend upon plants for all their organic food substances. Of course there are animals who eat no plant foods, but they depend upon animals which do, so that in the end plants are the only food producers.

The chief function of food is to provide energy to support the life of the consumer. This energy came from the sun, was locked

up in the food substance by photosynthesis, and has to be released or set free by oxidation. Except as it is oxidized, the energy in foods or fuels cannot be released. Hence the importance of oxidation as the key which unlocks the store houses of solar energy, and makes it available to support life. We do not know how the energy, thus released by oxidation, produces what we call "life," but we do know, that without it, no life exists and that, when oxidation ceases, life ceases too.

Outside of living energy there are two other general sources which man has learned to use, the power derived from fire and that obtained from water. In the case of heat energy we burn (oxidize) various fuels such as wood, coal, gas, or oil. All these fuels are originally derived from plant life. The energy which we set free from them, therefore, came originally from the sun. Someone has called coal "petrified sunshine"; this is almost true. When we warm our hands at the open grate, or heat our house with coal, or cook with gas, or light our rooms with electricity, we are setting free in various forms, the energy absorbed from the sun by plants.

But suppose the mill is run or the electricity used is generated by water power. Here again the sun is the final source because its heat has evaporated the water, which has risen as clouds, fallen on the hills as rain, and, flowing down again to the sea, turns the water wheels. To be sure there is no oxidation involved in this process, but it shows how the sun, either by its light or its heat, is the source of all our energy, both living and mechanical.

Circles in Nature. It might seem, since food is oxidized or fuel is burned to release its energy, that the supply would be exhausted and all life come to an end. Nature, however, works in circles, reclaims all waste, and aided by the sun, recombines them into useful compounds again.

The Carbon Circle. Carbon is one of the most necessary elements for all living things. Animals obtain it from plants and plants get it from the carbon dioxide of the air. Plants take this carbon dioxide from the air, combine it with water from the soil, and lock up within the starch which is formed the energy of the sun which formed it.

However, the carbon is not lost. When either plant or animal, fire or decay, oxidize these plant products, carbon dioxide is set free again in the same amounts as before, mixes with the atmosphere, and is ready for plant use again. No atom of carbon has ever been destroyed or produced by life processes; it is merely used over and over again.

The Oxygen Circle. Oxygen is equally important, both as

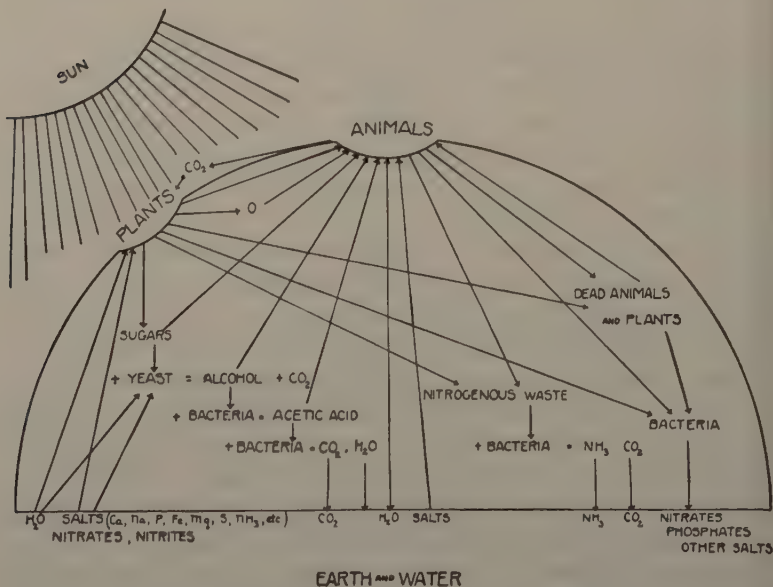


FIG. 160. Diagram illustrating the cycle of living matter and energy in animals, plants, yeast and bacteria. From Calkins.

being a part of all living tissue, and as the liberator of vital energy. It is taken from the air whenever plants or animals breathe, or wherever fire burns or substances decay.

All these processes combine the oxygen into carbon dioxide, water, or other oxides, and one might suppose that it was permanently removed from circulation, but this is not the case. Plants take this carbon dioxide and water, unite them to form

starch, set free in the air the oxygen again, and thus this circle is completed. A study of the diagrams will help to fix this in your mind.

Nitrogen Circle. Nitrogen, also, is absolutely essential to all living tissue and protoplasm as well as all proteid food. Plants obtain nitrogen compounds from the soil, mainly as soluble nitrates. They use them in making their living tissues, which in turn furnish to animals their only source of nitrogenous food.

Here again one would be justified in supposing that the nitrogen was out of reach of future use. If this were so, life would long since have ceased, as ordinary soil contains only enough nitrogen

CARBON-OXYGEN CYCLE

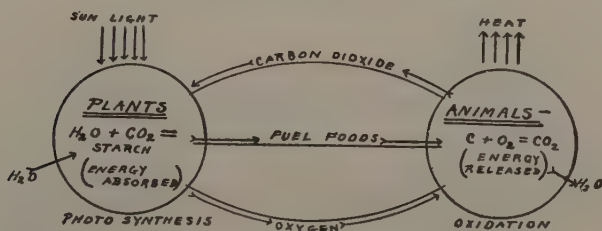


FIG. 161. Chart showing interdependence of plants and animals for oxygen and carbon dioxide.

compounds to last about thirty years, if none were replaced.

All waste excreted from animals contains nitrogen compounds, and in the course of nature this should get back to the soil as natural manures. Whenever a plant or animal dies, decay takes place, and much of its nitrogen is thus returned by the action of certain decay bacteria. However, neither manures nor decay would give back enough, especially as man disposes of all his sewage by washing it into rivers or ocean where it cannot get back to the soil from which it came.

Furthermore, much nitrogen is set free into the air by decay and oxidation in such a way that plants cannot use it, except it be combined with other elements. So there would be a serious

shortage if it were not for other means of return. It remains for certain bacteria, living in the nodules which they form on the roots of clover, peas, beans, alfalfa, and all members of this large family of plants, to aid in making good the loss.

These bacteria take the free nitrogen from the air, combine it into soluble compounds, and thus replace in the soil most of this essential element, which decay and oxidation had set free in the air.

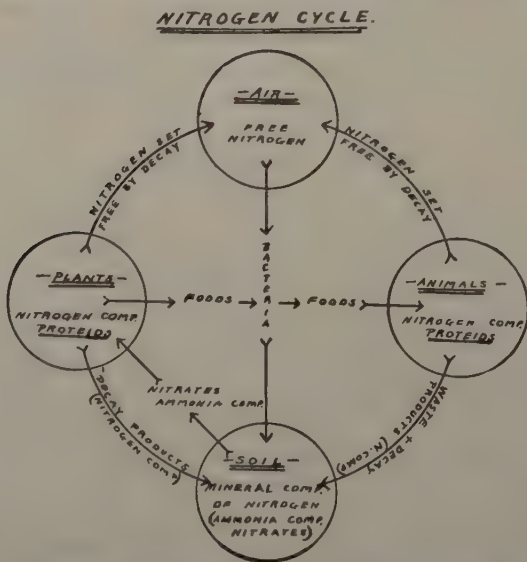


FIG. 162. Diagram showing how nitrogen compounds, after being used by plants and animals, are either returned to the soil by decay, or reclaimed from the air. This completes the "nitrogen cycle."

Although the atmosphere contains an enormous amount (80 per cent) of nitrogen, it is not in the form of compounds, and these plants of the pea family are the only ones that can use *free* nitrogen.

Another means by which free nitrogen of the air is combined into useful compounds is by the action of lightning, which converts some into oxides. These are washed back to the soil by rain and help in completing the circle.

In addition to these natural steps in the nitrogen circle we must

remember that man has learned to use the energy of nitrogen compounds in all his explosives and many other chemicals. This interferes seriously with nature's plan, for the firing of one twelve-inch gun wastes nitrogen enough to raise one hundred bushels of wheat. To repair this loss we are just learning to artificially combine the nitrogen of the air into useful compounds, and replace them in the soil as fertilizers. Unless this is done, the end of the nitrogen supply is in sight, due, as usual, to man's interference in nature's processes. He wastes nitrogen as sewage, chemicals, and explosives, so must do his part in completing the circle or suffer the consequences.

NITROGEN IN THE SOIL

<i>Removed by</i>	<i>Replaced by</i>
Life processes	Manures
Decay (some kinds)	Decay
Oxidation of useful forms	Bacteria
Waste of sewage	Electrical action
Industrial uses	Artificial processes
Explosives	Fertilizers

Other Elements. The circles which are followed by the other elements found in plant and animal tissue are not so complicated. Hydrogen comes and goes as water, of which there is a limitless supply in most regions. The sulphur, phosphorous, potassium, and other mineral compounds are usually abundant to begin with, and are not set free by decay, but come back to the soil in usable form.

If a soil becomes deficient in any of these, they are obtained elsewhere as natural mineral deposits and replaced as artificial fertilizer. In a state of nature this would never be necessary, as the plants would die and decay where they grew and so return their mineral salts to the soil that produced them. It is only when man removes his crops, and uses them elsewhere, that artificial replacement is necessary.

EVOLUTION OF LIFE FUNCTIONS (PLANTS)

Organism	Food Getting	Digestion and Assimilation	Respiration	Excretion	Reproduction	Motion and Sensation
Spore plants, bacteria and yeast	No chlorophyll, parasitic	By protoplasm direct	Oxygen from water through cell wall, for heat and energy	Through vacuoles and cell wall	"Multiplication by division"	Very little, or no motion or sensation
Seed plants						
1. Germinated seed	Food stored by parent in endosperm or cotyledons	Digestion by diastase, protoplasm assimilates	Cells take in oxygen, produces energy	Transpiration in leaf and stem	Cell division for growth only	Heliotropism, hydrotropism, geotropism
2. Adult plant	Leaves, CO ₂ and H ₂ O united by light Starch and N, S, P, make proteins	Each cell makes diastase, circulation, protoplasm assimilates Plants use more food for growth; animals use more for energy	Oxygen from air, via stomates and lenticels and intercellular spaces	CO ₂ and H ₂ O through air spaces, stomates and lenticels Wastes in fall of leaves	Cell division for growth New plants by fertilization Sperm + ovule form embryo and food (seed)	Plants move by growth of tissues Animals move by contraction of tissue

Plants reached height of development in composites
Further evolution hindered by lack of sensation and motion

SOME GENERAL BIOLOGIC PROCESSES

Organism	Food-getting	Digestion	Respiration	Excretion	Reproduction	Motion and Sensation
Protozoa, paramecium	Cilia, via gullet	By protoplasm direct	Dissolved oxygen from water, through cell walls	Through vacuoles and cell wall	"Multiplication by division"	Pressure and light sensation Motion by cilia
Crayfish	Claws, maxillipeds, maxillae, mandibles to mouth	Systems of organs for digestion, circulation, etc. Protoplasm assimilation As above	Gills, under carapace take oxygen from water. Gill bailer causes fresh flow Tracheae take oxygen from air. Blood loose in body. Oxidation in cells	CO ₂ by gill; waste from green gland	Cell division for growth. Fertilized eggs held on swimmerets	Sight, smell, touch, various motions of appendages, swimming and walking
Grasshopper	Maxillae, lips and mandibles, aided by sight and locomotion	As above	Oxygen from water through gill walls. Oxidation in cells	CO ₂ by spiracles. Urea by excretory tubes on intestine	Internal fertilization, eggs buried by ovipositor	All "senses." High instinct Rapid motion by legs, wings, etc.
Fish	Teeth and mouth for prehension; aided by senses, and locomotion	As above	Oxygen from water through gill walls. Oxidation in cells	CO ₂ by gill Urea by kidneys	Eggs externally fertilized, little parental care	All "senses" somewhat: lateral line for pressure, motion by fins, tail, etc., muscles in layers
Frog	Tongue, mouth, and teeth. Aided by senses and locomotion	Mouth, saliva (starch.) Gullet, mucous. Stomach, gastric (proteins, intestines, bile (fats), pancreatic. All food absorbed by villi carried by plasma. Assimilation by protoplasm	Oxygen from water through skin Oxygen from air through lungs Air "swallowed" carried to cells by red corpuscles. Oxidation in tissues	CO ₂ from lungs Other wastes from kidneys	Eggs externally fertilized, in masses, metamorphosis, Tadpole to frog	Usual senses, spindle-shaped muscles, arms and legs; later long and webbed. Land or water travel
Man	Essentially same as the frog; adaptations better; better coordination; success achieved in one line; that is, development of sensation toward reason					

Evolution of Life Functions. Biology teaches that all living things are alike in their fundamental life processes, that all forms are related by descent from common ancestors; that as development proceeds, they become better fitted to perform their life functions, or in other words, become more highly specialized.

The accompanying tables are intended to summarize this development in life processes, as shown in the forms which we have studied. It is necessarily much condensed, but careful study will reveal many of the facts brought out during the course.

COLLATERAL READING

Osmosis: *Fundamentals of Botany*, Gager, pp. 54-60; *The Living Plant*, Ganong, pp. 165-179; *Principles of Botany*, Bergen and Davis, pp. 36-39; *Introduction to Botany*, Stevens, pp. 35-39; *Plant Physiology*, Duggar, pp. 64-83; *Textbook of Botany*, Coulter, Vol. I, pp. 302-309; *Applied Biology*, Bigelow, pp. 85-97; *Elementary Biology*, Peabody and Hunt, pp. 32-38; *The Science of Plant Life*, Transeau, pp. 166-178; *General Physiology*, Eddy, pp. 136-142; *College Botany*, Atkinson, pp. 13-21.

SUMMARY

1. Osmosis in life processes (tabulated in text).
2. Oxidation, the release of energy.
 - Plants the ultimate source of food.
 - The sun the ultimate source of energy.
3. Circles in nature.
 - (a) The carbon circle (see diagram).
 - (b) The oxygen circle (see diagrams).
 - (c) The nitrogen circle (see diagrams).
 - (d) Other elements.
4. Evolution of life functions (tabulated in text).

CHAPTER LIV

THE HISTORICAL DEVELOPMENT OF BIOLOGY

Vocabulary

Spontaneous, without cause.

Mortality, death rate.

Enumerate, to make a list of, to number.

Rabies or **hydrophobia**, the disease caused by mad dog bite.

Virulence, disease producing ability.

Like all other sciences, biology has developed from small beginnings, by the labor, study, and sacrifice of many men over a long period of years. Biology might be said to have started when man first became intelligent enough to observe the plants and animals with which he was surrounded, and utilize or avoid them as he found best.

HARD WON KNOWLEDGE

Circulation. We gain our present knowledge so easily and take it so much for granted that we can hardly realize the struggles by which even our simplest facts were obtained.

Every child knows that the blood circulates in the arteries, but the ancients believed that they were air tubes and it was only in 1603, after much opposition, that Harvey was able to fully prove this fact of circulation.

Spontaneous Generation. We assume, as a matter of course, that any plant or animal springs from a parent like itself, but up to 1668 it was believed that maggots came from decayed meat, that frogs came from mud, and that living things were produced from non-living matter. At that date Redi discovered flies' eggs and larvae and proved that the maggots were produced by flies. The presence of bacteria in decaying substances was not explained until 1850-70.

At that time Pasteur and Tyndall showed that bacteria would not develop except when the medium had been exposed, and so proved, even for these minute plants, that bacteria were produced by bacteria, and in no other way.

The idea that life could come from dead matter was called the

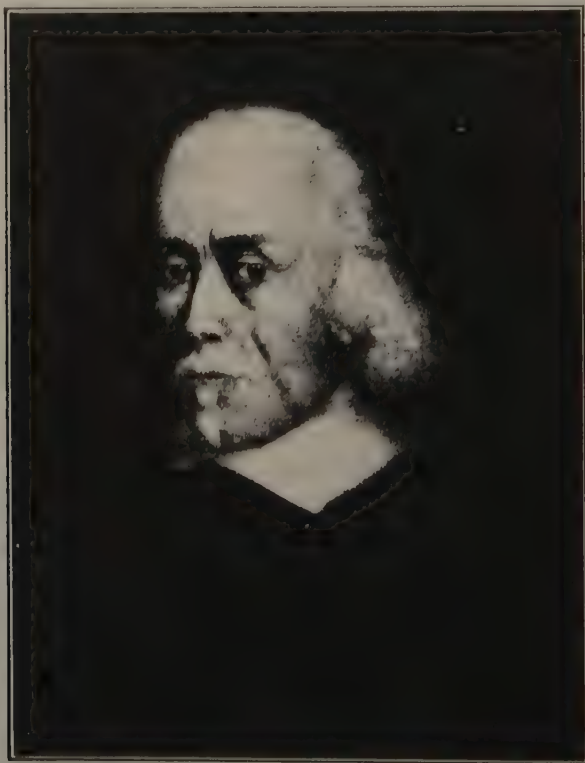


FIG. 163. William Harvey. 1578-1667. From Locy.

theory of "spontaneous generation," and died hard. This is now replaced by the belief that "all life comes from life."

Oxidation. We talk freely of oxygen and oxidation, but oxygen was not discovered until 1774 when Priestley obtained it and

demonstrated some of its properties. Even then scientists believed that when a substance burned it gave off something instead of combining with something (oxygen) as we now know to be the case.

Vaccination. All of us are vaccinated and think nothing of it, but before 1796, smallpox raged unchecked and was so common that about 95 per cent of all people had it. We little realize the struggle of Dr. Edward Jenner, an English physician, who was the first to suggest vaccination as its cure.

He observed that the dairy maids who had had cow pox (a mild form of smallpox) did not fall prey to the latter disease. Reasoning from this he proposed to inoculate people with cowpox as a protective measure, and suffered ridicule, opposition, and persecution before he could convince the public. Even now there are a few misguided individuals who oppose vaccination, even though its practice has made smallpox one of the rarest of diseases.

DEVELOPMENT OF BIOLOGY

It would be impossible to enumerate here all the famous names in biology or to sketch their contributions to our knowledge. Only a few can be mentioned, but there are books, like "Biology and its Makers" by Locy, which deal with the subject in fascinating style and treat of all the important discoverers.

A few of these are listed in the tabulation at the end of this chapter, and a glance at it will show two things, — how old some of our biologic ideas are, and how young is our definite knowledge sufficient to apply them. The Greeks theorized vaguely about evolution and development, but it was over two thousand years before Darwin and others proved it. Galen was the foremost physician of his time, but modern medicine scarcely had its beginnings till fifteen hundred years later.

Cells and Protoplasm. Hooke saw cell walls in cork bark in 1671, but it was nearly two hundred years before the importance of the cell as a unit of tissue structure was proven by Schleiden and Schwann in 1838–39. Both Schleiden and Schwann noticed

the jelly-like substance in the cells but it was not until 1846 that von Mohl called it "protoplasm" and fifteen years later, 1861, Schultze showed that it was the fundamental material of both plants and animals.

Louis Pasteur. Probably no one has applied biology to benefit mankind to a greater degree than Louis Pasteur, born in France in 1822: died 1895, "the most perfect man in the realm of science." In 1857 he showed the relation of bacteria to fermentation and greatly benefited the wine industry of France by his

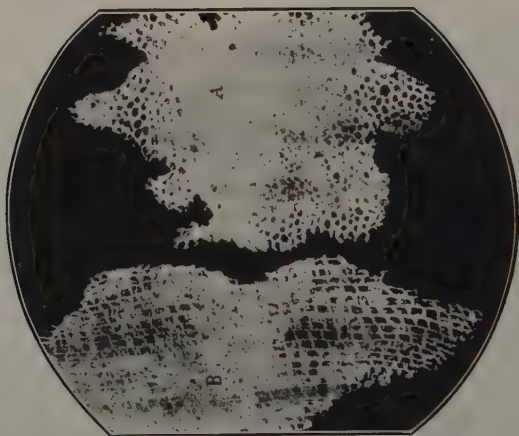


FIG. 164. The earliest known picture of cells from Hooke's *Micrographia* (1665). Edition of 1780. From Locy.

investigations. In 1865-68 a disease attacked the silk worms of France and Italy and threatened to wipe out the industry. Pasteur traced this to bacterial attack, and was able to suggest means by which the silk business was saved.

Later his attention was turned to chicken cholera and other animal diseases and from his researches along these lines he developed the treatment by inoculation, and laid the foundation for all modern serum and anti-toxin treatments.

His most famous work was done in the treatment of rabies,

which consists in injecting weak doses of the hydrophobia germs into the blood of a person bitten by a mad dog. By gradually increasing the virulence of the injections anti-toxins are built up in the patient's body and resist the real attack of the disease. By this treatment the mortality has been decreased from practically certain death to less than one per cent.

The world owes to Pasteur the foundation of all our modern methods in bacteriology, our serum and anti-toxin treatments, and all the lives that have been saved thereby. Possibly more people owe their lives to the results of his work than to that of any other man who ever lived.

Other Victories over Disease. At the Pasteur Institute many discoveries have been made in the line of inoculation against lock-jaw (tetanus), bubonic plague and other germ diseases, but none has saved more lives than the anti-toxin for diphtheria. This was developed by Roux, a fellow worker with Pasteur and by von Behring, a German bacteriologist in 1894. By this use a disease which annually caused the death of thousands of children, now has its rate reduced about 80 per cent and if treatment is given early in the case, recovery is almost certain.

Among others who have labored in the work against germ disease may be mentioned Robert Koch, who studied the relation of bacteria to human disease, especially in the case of tuberculosis and Asiatic cholera. He was the first to identify these bacteria and though he devoted his life to the work, did not discover a specific cure for tuberculosis. However, his work has enabled us to take preventive measures which are greatly aiding in suppression of this worst of the "ills that flesh is heir to."

Antiseptic and Aseptic Surgery. Sir Joseph Lister, an English surgeon, was the first to fight the germs of the operating room by the use of antiseptics, such as carbolic acid. This one discovery has done more to prevent death by infection after operations than any other of recent times. Modern surgery aims to keep its wounds *aseptic*, that is, free from all germs by careful methods of sterilization, but still relies on *anti-septics* to kill any germs that may have found entrance. Before Lister's time infection of op-

erative wounds was to be expected — now it would be considered evidence of gross carelessness and very rarely occurs.

Among other names to be associated with modern advance against disease is that of Paul Ehrlich. He is famous for his study of the blood as related to immunity to certain diseases, and es-

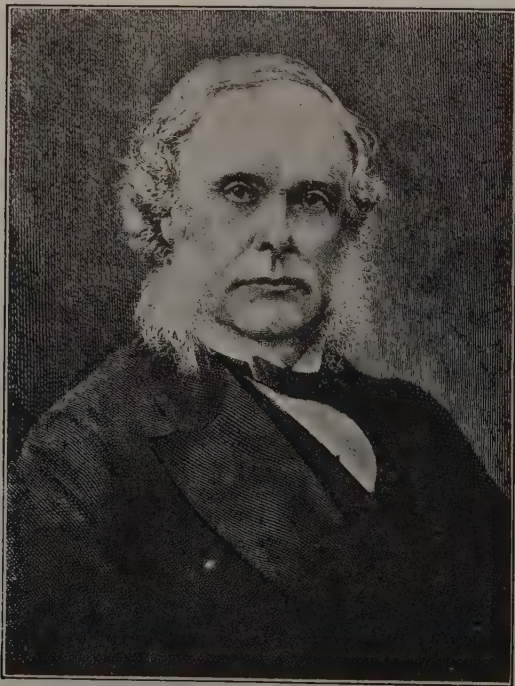


FIG. 165. Sir Joseph Lister. 1827–1912. From Locy.

pecially because of his successful method of treating syphilis, which before had been incurable.

Another scientist who worked along similar lines was the Russian, Metchnikoff, who was the first to discover the functions of the white corpuscles in combating disease germs in the blood.

Carrell and Flexner are two American scientists who are working at the present time to carry the fight against disease to a more

successful conclusion. Among many other discoveries, Carrell has developed a very successful method of treating infected wounds which saved thousands of lives during the war. Flexner has been investigating anti-toxin treatments for infantile paralysis and similar diseases.

Charles Darwin. If applied biology owes its greatest debt to Pasteur and his successors, certainly theoretical biology owes

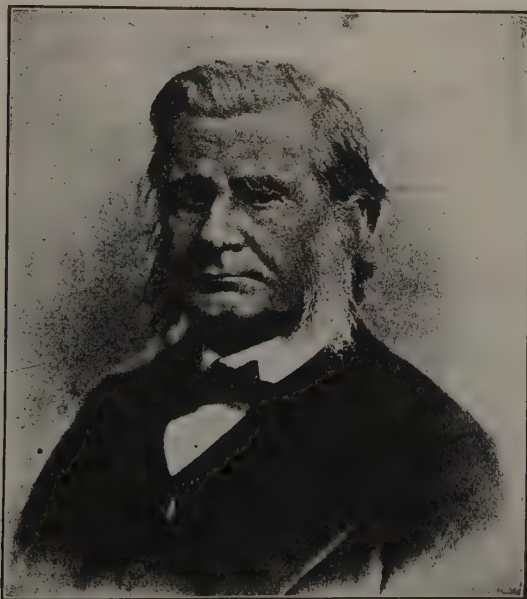


FIG. 166. Thomas Henry Huxley. 1825-1895.
From Locy.

more to Charles Darwin and his co-workers than to any other man. His work along the line of evolution and natural selection revolutionized all modern thought and has been briefly described in Chapters 34 and 35.

Associated with him was Alfred Russell Wallace who reached the same conclusions as Darwin, though working from different facts and entirely independent of his ideas.

Huxley, another English scientist, defended and explained Darwin's theories, and Herbert Spencer, also English, applied them to all lines of scientific thought. Upon the foundation laid by these men, all modern biology is based.

Mendel's Law of Inheritance. In 1860 an Austrian priest, by



FIG. 167. Gregor Mendel. 1822-1884. Permission of Professor Bateson. From Loey.

the name of Gregor Mendel, began raising peas in his garden at Brün. He was not so much interested in the flowers or the abundance of the crop as in other apparently less important matters.

He noted the shape of seed, and their color, — the shape and color of the pods, — the height of the plant and other similar characteristics. He kept each kind separate and cross-pollinated

them himself, so knew exactly the ancestry of each new set of descendants. After years of patient experiment and careful record he reached some conclusions. He found that if he crossed tall with short that the next generation were hybrids but tall in appearance, — that is, tallness had overcome shortness as a characteristic in that generation.

Many characteristics were found to be stronger at first and were called "dominant" characteristics. Those which were crowded out were called "recessive." However when these

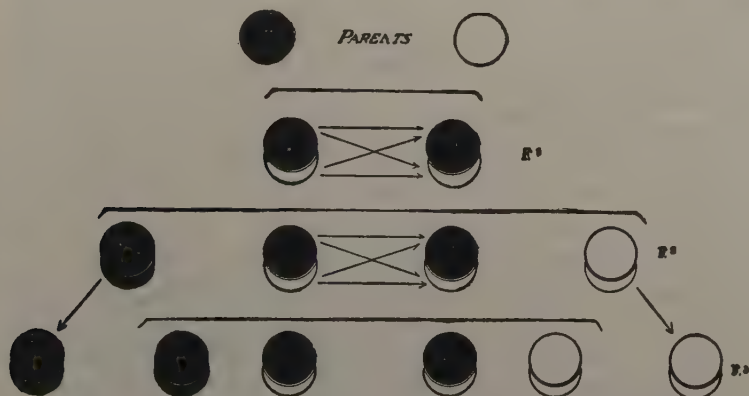


FIG. 168. Diagram to show the segregation and re-combination of the factors (black and white) in the gametes, and the presence of both in the hybrid F'. (From Morgan, *see* Calkins.)

hybrids were bred together both the original characteristics reappeared in a constant proportion of tall, short, and tall hybrids.

The reason is that the two characteristics remained *separate* in the hybrids and did not blend, hence when hybrid was bred with hybrid the next generation would combine these characteristics according to the mathematical law of probabilities or chance.

To illustrate, let x and y stand for any two non-blending characteristics. The first crossing would produce hybrid offspring having xy characteristics, but if x were dominant, y would not appear.

However if these xy hybrids are crossed together, four possible combinations may occur, thus:

Joining x with x producing xx offspring.

"	x	"	y	"	xy	"
"	y	"	x	"	yx	"
"	y	"	y	"	yy	"

Of course the xy and yx individuals are of the same kind and are also like their xy hybrid parents, but the xx and yy offspring have those characteristics *only* and are pure bred: their offspring with either x or y respectively would produce pure x or pure y characteristics, despite their mixed ancestry.

Of course breeding is not so simple as this, because it cannot be limited to one characteristic at a time, and some characteristics do blend or average in the hybrids, but the law of inheritance, known as Mendel's Law, has been proven true and is of great value in plant and animal breeding.

Though Mendel published his conclusions in 1865 and 1869 little notice was taken of them and he died in 1884 without recognition. Later the same conclusions were independently reached by three other scientists who would have been credited with an important discovery, but in 1900 Mendel's papers were found and his long delayed appreciation arrived, sixteen years after his death.

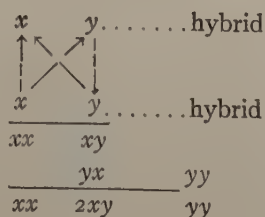
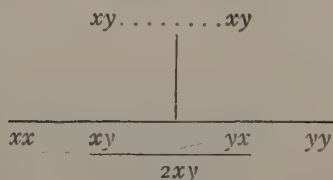
Briefly stated, his law comprises three facts:

1. Pure bred mated with pure bred of *same* kind give offspring pure bred.
2. Pure bred mated with pure bred of *different* kind, — hybrid offspring.
3. Hybrid mated with hybrid the offspring will be one-half hybrid, one-quarter pure bred like grandfather, one-quarter pure bred like grandmother.

Law I. Pure bred with pure bred of same kind, x plus x makes xx .

Law II. Pure bred with pure bred of different kind, x plus y makes xy .

Law III. Hybrid bred with hybrid, xy plus xy makes xx , $+2xy$, $+yy$ or stated differently.



Luther Burbank. No one has made such successful application of these laws of inheritance as has Luther Burbank. For years he has been performing what might be called biologic miracles, on his farm in Southern California.

A complete list of the new or improved plants which he has developed, would occupy a whole chapter, but some of the most famous are

1. The Burbank potato which has increased our crop by millions of dollars and is said to have prevented the potato famine that formerly devastated Ireland.

2. The spineless cactus which provides abundant stock food for regions where none was to be had.

3. The "Primus Berry," a valuable cross between the dewberry and raspberry. It differs from both its ancestors and is the first absolutely new species ever produced by man.

4. A cross between the plum and apricot called the "Plumcot" which has the good qualities of both ancestors and some of its own.

5. The pitless plum and thin-shelled walnut explain themselves.

6. Among flowers, the Shasta daisy six inches in diameter, and the ten-inch poppy, are well known.

He works by cross-pollination, grafting, and rigid selection. Specimens are collected from all over the world, raised in his gardens, and crossed to develop desirable characteristics. They are then cultivated in enormous numbers, to take advantage of all possible variations, and only the best are selected.

Thus, by combining a deep knowledge of biologic laws, with

marvelous skill in their use, Mr. Burbank has developed plant breeding to a degree never approached before.

COLLATERAL READING

Encyclopedia references on all persons and topics mentioned. *Biology and its Makers*, Locy, entire; *Main Currents of Zoölogy*, Locy, entire; *Elementary Biology*, Peabody and Hunt (Malaria), pp. 47-56, Pt. I; *Life of Pasteur*, Frankland; *Children's Stories of Great Scientists*, Wright; *General Zoölogy*, Linville and Kelly, pp. 436-451; *Zoölogy*, Parker and Haswell, pp. 628-649; *General Principles of Zoölogy*, Hertwig, pp. 7-67; *General Zoölogy*, Pearse, pp. 6-12; *Manual of Zoölogy*, Hertwig-Kingsley, pp. 7-56; *Biology*, Calkins, pp. 219-232 (Mendelism); *Mechanism of Mendelian Heredity*, Morgan, etc., entire; *The Next Generation*, Jewett, pp. 20-24 (Mendelism).

Name	Date	Nationality	Contribution to Biology
Heracitus	500 B.C.	Greek	Theorized vaguely on the idea of evolution
Empedocles	450 B.C.	Greek	Suggested natural selection and survival of the fittest
Aristotle	350 B.C.	Greek	Founder of zoölogy. Emphasized importance of observation
Pliny	79 A.D.	Roman	Long considered very high authority
Galen	169 A.D.	Greek	Wrote first popular book on "Natural History"
Vesalius	1542	Belgian	Founder of ancient medical science and physiology
Harvey	1603	English	Founder of modern anatomy and human dissection
Malpighi	1661	Italian	Worked out circulation of the blood. Studied embryology
Leewenhoek	1667	Dutch	Discovered capillaries in the lungs
Redi	1668	Italian	Described development of chick embryo
Hooke	1671	English	Invented microscope (?) Saw bacteria but did not understand them
Borelli	1680	Italian	Disproved spontaneous generation. Wrote on insects' life
Hales	1727	English	Discovered cell walls in cork bark
Linnæus	1753	Swedish	Worked out microscopic structure of some plants
Priestley	1774	English	Discovered function of muscles, acting with bones as levers
Jenner	1796	English	Discovered plant respiration
Sprenkel	1796	German	Devised modern method of plant classification and naming
Lamarck	1801	French	Discovered oxygen; studied plant respiration
Audubon	1820	American	Discovered vaccination
Schleiden	1838	German	Studied fertilization and insect pollination
			Invented a scheme of animal evolution based on inheritance of acquired characteristics. Not now accepted
			First to use the term "Biology"
			Notable bird student and artist
			Discovered cell as unit of plant structure. (Founded "cell theory")

Name	Date	Nationality	Contribution to Biology
Schwann	1839	German	Discovered cell as unit of animal structure. (Founded "cell theory.") Worked with Schleiden.
Agassiz	1840	Swiss	Wonderful teacher of zoology, Harvard
Mohl and Schultze	1846	German	Studied and named protoplasm
Pasteur	1857	French	Studied bacteria in relation to fermentation and disease of plants and animals. Developed use of serums and antitoxins
Darwin	1859	English	Proved evolution by natural selection Wrote "Origin of Species"
A. R. Wallace	1859	English	Reported work similar to Darwin's based on geographic distribution
Huxley	1863	English	Defended and explained Darwin's theory
H. Spencer	1865	English	Developed "laboratory method" of teaching Applied evolution to all sciences Originated expression "survival of the fittest"
Mendel	1865	Austrian	Discovered law of heredity
Lister	1867	English	Developed antiseptic surgery
Ehrlich	1875	German	Studied blood composition. Discovered cure for syphilis
Metchnikoff	1875	Russian	Discovered white corpuscles and their functions
Koch	1880	German	Proved relation of bacteria to human disease Discovered germs of tuberculosis and Asiatic cholera
Laveran	1880		Discovered malarial parasite in mosquito
Roux and Behring	1894	French and German	Antitoxin treatment for diphtheria
Reed, Lazear	1898	American	Discovered relation between mosquito and yellow fever
Howard	1898	American	Discovered relation between fly and typhoid
Burbank	1900	American	Applied modern biology to plant breeding
Carrell	1906	American	Developed methods of wound antiseptics, later used in war
Flexner	1910	American	Developed modern serum and antitoxin treatment

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